THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE III. VOL. III.

No. XI.—NOVEMBER, 1886.

ORIGINAL ARTICLES.

I.—The Metamorphosis of the Lizard Gabbros.[1]

By J. J. H. Teall, M.A., F.G.S.

(PLATE XIII.)

If we take a general view of the present position of geological science, we are struck by the fact that, although there is substantial agreement amongst geologists on matters relating to the origin of the rocks usually designated as aqueous and igneous, the greatest diversity of opinion prevails with regard to the circumstances under which the so-called metamorphic rocks have been produced. Every fragment of evidence calculated to throw light on the origin of these rocks, therefore, deserves the most careful consideration. Of recent years special attention has been directed to the effects of mechanical energy in modifying the mineralogical and structural characters of rocks originally formed by aqueous and igneous agencies; and a suspicion has been aroused that it is in this direction that we must look for a solution of many of the problems connected with the origin of the crystalline schists. A visit to the Lizard Peninsula of Cornwall during the present summer has convinced me of the immense importance of this view so far as that district is concerned. That portion of the peninsula which lies south of a line drawn from Porthalla on the east to Polurrian Cove on the west is formed partly of igneous rocks—such as gabbro, greenstone, serpentine, and granite—and partly of crystalline schists. The igneous rocks, in certain places, become foliated and schistose and sometimes show a definite banding due to a variation in the relative proportions of the different constituents. In other words they present characters which are usually regarded as distinctive of the crystalline schists. There is, moreover, evidence to show that these characters are mainly the result of a yielding to earth-pressure subsequent to the consolidation of the original rock. At the present moment, having just returned from the district, I am unable to treat the subject from a general point of view with any prospect of success; but it has occurred to me that some details with regard to one of the rocks may not be without interest to members of the Association.

The gabbros of the Lizard have been noticed by many previous writers, including Dr. Boase,[2] Mr. Majendie,[3] Sir Henry de la Beche,[4]

[1] Paper communicated to Section C of the British Association.

[2] Trans. Geol. Society of Cornwall, vol. iv. p. 330.

[3] *Ibid.* vol. i. p. 36.

[4] Report on the Geology of Devon and Cornwall, 1839.

and Prof. Bonney.[1] Their mineralogical composition, geographical distribution, and structural characters were described by the older observers. Prof. Bonney added many facts on these points and gave in addition a description of their microscopic structures. As I wish on the present occasion to refer to them for the purpose of establishing a definite proposition with regard to the origin of certain structures which they possess, I must ask permission to recapitulate the facts, and at the same time to add one or two from my own observation.

Gabbro occupies an area of six or seven square miles in the neighbourhood of St. Keverne, and forms the elevated tract of land known as Crousa Down. This great mass comes down to the sea and forms the coast-line from Coverack to Manacle Point. It is traversed by veins and dykes of a fine-grained rock generally known as "greenstone." This greenstone is essentially composed of plagioclase and hornblende, the latter mineral often belonging to the uralitic and actinolitic varieties. It is, as Prof. Bonney has pointed out, an altered plagioclase-augite rock, and must be classed with the epidiorites (Gümbel) of the Fichtelgebirge and the Hartz. In some instances the felspars give lath-shaped sections which penetrate the fibrous aggregates of secondary hornblende in such a way as to prove conclusively that the parent rock must have been an ophitic dolerite.

The amount of this "greenstone" or "epidiorite" associated with the gabbro increases towards the north until it exceeds that of the latter rock. Although the junctions of the gabbro and the greenstone are perfectly sharp, it is impossible to represent the distribution of the two varieties on a small scale map in consequence of the way in which they alternate with each other. Manacle Point, which is represented as greenstone on the Survey Map, consists for the most part of gabbro in which veins and dykes of greenstone are very common.

The northern limit of the gabbro-greenstone area above referred to occurs in the neighbourhood of Porthoustock. The adjacent rock is hornblende-schist, but the actual junction, which is probably a fault, is concealed by a small shingle beach. The southern limit of this mass comes out on the sea-shore by the small village of Coverack. The geology of this locality has been fully described by Prof. Bonney, to whose paper reference must be made for details. The only point that need be mentioned here is that the normal gabbro is seen to be intrusive in serpentine and also in a rock, intimately associated with the serpentine, which consisted originally of a basic felspar and olivine and which appears to be identical with the troctolite or forellenstein of Neurode in Silesia.

South of Coverack the greater part of the district is occupied by serpentine in which veins and dykes of gabbro frequently occur. The mass of gabbro which ranks next in importance to that of Crousa Down is exposed on the sea-coast west of Lankidden Cove. It forms the headland of Karakclews, and may be followed along the coast

[1] Quart. Journ. Geol. Soc., vol. xxxiii. 1877, p. 884.

for a distance of about a quarter of a mile. A mass of precisely similar gabbro occurs inland at Gwinter. The two portions are doubtless continuous, as represented on the geological map; and if so, they form a dyke-like mass running inland in a N.W. direction. The Karakclews gabbro is bounded on both sides by serpentine into which it was intruded. Marked signs of disturbance occur near both junctions and throughout the mass; but, notwithstanding this, veins of gabbro may occasionally be seen running out from the larger mass into the surrounding rock.

Another considerable exposure of gabbro occurs on the shore north of Pen Voose,[1] near Landewednack. It is bounded on the north by serpentine with gabbro veins, and on the south by a remarkable group of rocks which Prof. Bonney terms "the granulitic series." The gabbro is here traversed by veins of granite and mica-diorite which will doubtless repay careful examination, but which need not be further referred to on the present occasion.

The principal mineralogical constituents of the Lizard gabbros are plagioclase, augite or diallage, hornblende and saussurite. Olivine is present in certain varieties, but does not appear to have been very widely distributed in these rocks. In the least altered rocks the plagioclase occurs in the form of grains of tolerably uniform size and having nearly equal dimensions in the different directions. The grains show broad lamellar twinning, and not seldom two sets of lamellæ are seen crossing each other at right angles. This is the feature which is usually regarded as indicating simultaneous twinning on the albite and pericline types. The extinction angles in thin sections of the rock show that the felspar belongs to the labradorite-anorthite series, but I have not as yet been able to make a more precise determination. In the more or less altered gabbros we see various stages of the replacement of felspar by white or cream-coloured saussurite. The first stage consists in the development of white spots in the glassy felspar substance. These spots appear snow-white under the microscope by reflected light, and opaque or brown by transmitted light. They never exhibit any definite form or cleavages. By the increase in the number and size of these white spots and by other changes the felspar gradually passes into saussurite. This substance sometimes occurs in masses of considerable size, and it is then remarkable for its toughness and hardness. Its specific gravity is about 3·1. Microscopic examination shows that it is an aggregate and not a simple mineral, but it is by no means easy to determine the precise character of the different constituents. Cathrein's[2] investigations led him to the conclusion that saussurite is an aggregate of zoisite or epidote and felspar, usually albite; with variable quantities of actinolite and tremolite as accessory constituents.

[1] There is some confusion about the naming of this locality. The small bay to the north of which the gabbro is exposed is named the Balk on the one-inch map and Parn Voose on the twenty-five inch map. The inhabitants of this district say that this bay is called Pen Voose and that the place where the life-boat is kept, otherwise known as Church Cove, is Parn Voose. As the maps do not agree, I have followed the inhabitants.

[2] Ueber Saussurit, Zeit. f. Krystallographie, vol. vii. p. 234.

I have not as yet been able to find a saussurite in the Lizard District answering to Cathrein's description.[1]

The felspars of certain gabbros in which the development of saussurite has not taken place at all, or has only occurred to a very limited extent, often give evidence of having been affected by profound mechanical disturbances. The twin lamellæ are frequently bent and, when the limit of elasticity has been exceeded, the crystal grains have been fractured. The extinction is not sharp and definite. Dark shadows sweep across the sections as the stage is rotated. In slides exhibiting these characters large felspars are often seen to break up, in certain places, into aggregates of minute, colourless, and for the most part simple grains. Such aggregates must certainly be regarded as of secondary origin, for they are entirely unknown in the unaltered felspar-diallage gabbros and frequently contain needles of actinolite, a mineral undoubtedly of secondary origin. They correspond to the felspar-mosaic of Lossen.[2]

The pyroxene in the least altered rocks is a pale green diopside. In microscopic sections it is almost colourless. Cross sections show an optic axis in convergent polarized light and frequently the two pinacoidal as well as the two prismatic cleavages. Longitudinal sections give a maximum extinction of about 40°. The mineral is therefore a monoclinic pyroxene. In addition to the cleavages above mentioned, we find occasionally incipient stages of diallagic lamination. This lamination is not as a rule persistent throughout the crystal, but limited to the neighbourhood of cracks. In the ordinary gabbros the pyroxene is a true diallage with a decided bronzy lustre on the planes of easy separation, which planes run parallel with the orthopinacoid. In some of the coarse-grained rocks the diallage crystals often measure two or three inches across.

The change of pyroxene into hornblende has been described and illustrated by Prof. Bonney. It is a common feature in the Lizard gabbros and often accompanies the change of felspar to saussurite. Many different varieties of secondary hornblende may be observed depending on variations in colour and habit. Sometimes the hornblende occurs in the form of homogeneous crystalline grains with strongly marked cleavages. This variety may be termed compact hornblende. At other times the hornblende is distinctly fibrous, and at others it occurs in the form of needles. The two latter varieties are generally termed uralitic and actinolitic respectively. Actinolitic hornblende frequently forms radiating fringes round the

[1] A saussurite composed of zoisite and albite occurs in Sangomore Bay near Durness, Sutherlandshire. Under the microscope this is seen to consist of minute colourless prisms embedded in a colourless felspathic matrix. The prisms possess a high refractive index, weak double refraction, cross-jointing at intervals, and give straight extinction. Small fragments of the felspar with which they are associated may occasionally be obtained and when tested in the Bunsen's burner give the flame colouration and fusibility of albite. In the mass this saussurite is white or a very pale pink. It contains hornblende and is associated with a felspathic gabbro in which the diallage has been converted into uralite and actinolite.

[2] Studien an metamorphischen Eruptiv- und Sedimentgesteinen, Jahrbuch d. k. preuss. geol. Landesanstalt für 1883 und 1884.

uralitic variety or round a crystal of diallage partially changed to uralite. The hornblende may be either green, brown, or colourless. One of the green varieties is remarkably brilliant and of that tint which led to the introduction of the term smaragdite. The gradual replacement of diallage by hornblende is a most striking feature in the Lizard gabbros. The two minerals bear an inverse relation to each other so far as distribution is concerned. As the one increases, the other diminishes.

Olivine does not appear to have been abundant or widely distributed in the normal gabbros. It occurs sparingly in an unaltered rock from Coverack, and in this case is perfectly colourless in thin sections and traversed by irregular cracks, along which magnetite has been formed. In some of the more altered gabbros it is represented by serpentinous pseudomorphs.

The minerals above referred to occur in very different proportions in the different rocks, and in different portions of the same rock-mass. We thus have an endless number of mineralogical varieties. The principal variations are due to the gradual replacement of felspar by saussurite and of diallage by hornblende. The two extreme types may therefore be designated felspar-diallage gabbro, and saussurite-hornblende gabbro; the former representing the original rock and the latter the extreme of mineralogical metamorphism. Between these two extreme types there are innumerable intermediate varieties. As a rule the change in one mineral is accompanied by a change in the other; but this is not invariably the case. We may thus have felspar-hornblende gabbros and saussurite-diallage gabbros. If we wish to indicate the mineralogical character of any intermediate form, we can do so by using a compound term made up of the names of the substances occurring as constituents. The number of actual varieties present is the number of possible combinations of the four principal constituents taken two, three, and four together. The introduction of olivine gives rise to other varieties, but, as already stated, I am inclined to think that this mineral was absent from considerable masses of the original rock.

If we eliminate hornblende and saussurite, both of which are undoubtedly secondary minerals, then the original felspar-bearing rocks of the gabbro-type occurring in the Lizard Peninsula must have comprised plagioclase-augite rocks, plagioclase-augite-olivine rocks, and plagioclase-olivine rocks. By the gradual disappearance of the felspar these rocks passed through the picrites into the peridotites, which are now represented by the serpentines. Felspar-bearing serpentines occur at the Rill Head near Kynance. Looking at the Lizard district as a whole, we are struck with many points of resemblance between it and the Tertiary volcanic district of the West of Scotland described by Prof. Judd.

We have now to consider the structural characteristics of the Lizard gabbros. In the first place, we notice varieties depending on variations in the sizes of the individual constituents. Such variations are characteristic of all masses of gabbro. In the coarsest varieties the individual crystalline grains often measure as much as

two or three inches across. These extremely coarse varieties are often distributed with considerable irregularity through large masses of the finer-grained rocks; not seldom, however, they occur as narrow veins and dykes in the serpentine. The dominant gabbro is a rock which would simply be described as coarsely crystalline. Fine-grained varieties are not known. The junction with greenstone or epidiorite is always sharp, and there is no evidence in the Lizard district, so far as I know, of a gradual passage from gabbro into dolerite and basalt. The "greenstones" are undoubtedly altered dolerites, some of which were ophitic, but their junctions with the gabbro are, as already stated, always sharp.

The mutual relations of the individual constituents in the unaltered gabbros are those of typical granitic rocks; in other words, no single mineral appears to have possessed any special advantage over any other so far as the conditions favourable to the development of crystalline form are concerned. Each mineral occurs in the form of crystalline grains.

In addition to variations of structure depending on variations in the sizes of the individual constituents, there are others, of a most important character, dependent on the mode of arrangement of these constituents in the rock-mass. From this point of view the gabbros of the Lizard may be divided into two groups: (1) the massive, and (2) the foliated gabbros. These two varieties are not, however, separated from each other by any hard and fast line. In the massive gabbros the individual constituents are not arranged in any definite manner; in the foliated gabbros a parallel structure is more or less pronounced. It is convenient in speaking of the foliated gabbros to recognize two principal types which may be designated by the terms *flaser-gabbro* and *gabbro-schist*. In the flaser-gabbro the parallel structure, though distinct, is not accompanied by any marked fissility. The constituents are white saussurite and dark aggregates of diallage and hornblende. These constituents are more or less lenticular in form and the flat surfaces of the lenticles lie parallel to each other, thus producing the foliated structure. The gabbro-schist is a rock of finer grain, with a strongly-marked schistosity. It can be broken into flat slabs like a hornblende schist. Indeed the rock may sometimes be called hornblende-schist without doing any violence to the latter term. Although it is convenient to use the expressions flaser-gabbro and gabbro-schist, it must not be supposed that there is any hard and fast line between the rocks designated by these terms. They shade into each other by the most insensible gradations. One very interesting structural variety which is, in some respects, intermediate between flaser-gabbro and gabbro-schist, may be termed augen-gabbro. In this variety the streaks which define the schistosity sweep round "eyes" of diallage, which thus remind one strongly of the "eyes" of felspar in augen-gneiss. (See Plate XIII.)

We have now to consider the distribution of the different structural varieties. The gabbro to the north of Coverack is on the whole massive; nevertheless here and there foliation makes its

appearance. In the neighbourhood of the village the veins and dykes of gabbro are often foliated, and every transition may be observed from massive gabbro to gabbro-schist. At Karakclews Headland foliation has been developed in a most striking manner, and affects, with a few local exceptions, the entire mass, which is more than a hundred yards in width. The general strike of the foliation is approximately N.W. and S.E., but there is no absolute constancy in the direction; slight deviations occur sometimes on the one side and sometimes on the other. One important feature in the Karakclews mass is the distinctly banded character of certain portions, particularly those near the southern junction with the serpentine. Light and dark bands several inches in thickness alternate with each other, and with the ordinary flaser- and augen-gabbro, so that the mass as a whole simulates a stratified series. The small dykes of gabbro in the serpentine near Karakclews are often foliated, and not seldom one may see the transition from massive gabbro to gabbro-schist taking place in the space of a few inches.

Another locality where foliation is well developed is north of Pen Voose near Landewednack. The main mass of gabbro is separated from serpentine and other rocks on the north by a well-marked fault-plane. In the immediate neighbourhood of this plane the gabbro is foliated, and passes into a fine gabbro-schist. Foliation also makes its appearance in the main mass, which is here intimately veined with mica-diorite and granite. It is frequently developed near the junction of the gabbro with one of the other rocks. In the small bay known as Pen Voose a lenticular mass of saussurite-hornblende gabbro, measuring about five feet in the longest diameter, occurs in Prof. Bonney's granulitic series. This is evidently not an intrusive tongue, but a lenticular mass which owes its form and position to earth-movements acting after the consolidation of the rock. It is conspicuously foliated parallel with the junction surfaces.

It is instructive to compare the mineralogical with the structural varieties. Foliation is absent from the felspar-diallage rocks. As the foliation becomes more and more pronounced, the diallage is gradually replaced by hornblende, and the felspar undergoes a change resulting for the most part in the development of saussuritic aggregates. In the most perfect gabbro-schist the diallage has entirely or almost entirely disappeared, and its place has been taken by hornblende. It must not, however, be supposed that the mineralogical change is invariably accompanied by the development of foliation. Many of the saussurite-hornblende gabbros are as massive as the original rock. In a paper on the "Metamorphosis of Dolerite into Hornblende-schist" I have pointed out similar relations between structural and mineralogical characters in the case of the Scourie dykes. A molecular rearrangement may take place in a massive rock without the development of foliation; but there is no reason to believe that foliation of the kind referred to in this communication can take place without molecular rearrangement.

The principal question which now remains for consideration is the

origin of this foliation. Is it an original or secondary structure? That it is due to a differential movement in the mass after the separation of the individual constituents will I think be admitted on all hands. The only question that can arise is whether this movement was in any way connected with the intrusion of the rock. The facts appear to me to point very decidedly to the conclusion that it is a secondary structure due to earth-movements acting upon the solid rock. That the Lizard district has been profoundly affected by earth-movements is apparent on every hand. The rocks have been folded, faulted, crumpled, twisted, and in some places brecciated by the intense pressures that have acted upon them. The evidences of mechanical disturbance are not limited to any one variety of rock or to any one district. They abound in every portion of the district, though their effects are more pronounced in certain localities than in others. If we attempt to determine the precise nature of the earth-movement, we are met with considerable difficulty on account of the superposition of the effects of distinct movements. The earlier movement, and the one which I suspect produced the greater part of the foliation in the gabbros, appears to have acted so as to produce a strike about N.W. and S.E. or N.N.W. and S.S.E. This earlier movement was, however, certainly followed by one producing faults which run approximately in an E. and W. direction. The latter direction agrees with one of the great post-Carboniferous disturbances, and the faults which run in this direction probably belong to those disturbances. That the two sets of earth-movements above referred to are the only ones that have acted upon the district I am by no means prepared to say; but that these two have acted is shown by facts which may be observed at Porthalla, George Cove and Kynance.

That the foliation in the gabbros is one of the results of the pressure- or regional-metamorphism which has operated upon the district, is rendered at once probable when we compare the Lizard gabbros with those of the West of Scotland. The latter consist mainly of felspar-diallage rocks, and are not foliated; the former are largely composed of saussuritic and hornblendic rocks, and are often conspicuously foliated. The Lizard district has been profoundly affected by earth-movements, whereas the Tertiary volcanic district of the West of Scotland has not been so affected.

This argument is in itself not conclusive, but it becomes greatly strengthened when we consider the distribution of gabbros of the Lizard type. They have been described by Dr. Reusch[1] from the Bergen Peninsula, by Prof. Lehmann[2] from the granulitic region of Saxony, and by Mr. Hatch[3] from the Tyrol. Each one of these districts gives independent evidence of having been subjected to pressure-metamorphism. Perhaps the most convincing proof that the structure is the result of movement after the consolidation of the

[1] Die Fossilien führenden krystallinischen Schiefer von Bergen in Norwegen, Leipzig, 1883.

[2] Die Entstehung der altkrystallinischen Schiefergesteinen, Bonn, 1884, p. 190.

[3] Tsch. Min. Mitth, Band VII. (1885), p. 75.

rock is, however, furnished by its relation to fault-planes. A rock must necessarily be solid before it can be faulted. Now, we find at Pen Voose near Landewednack, that massive gabbro passes over into gabbro-schist at a fault-plane, and that the foliation in the gabbro is such as would be produced by a shearing motion parallel with the fault-plane. Taking all the facts into consideration, we appear to be justified in concluding that the foliation in the Lizard gabbros is the result of pressure- or regional-metamorphism. It seems also probable that the replacement of felspar and diallage by saussurite and hornblende has been largely determined by the same agency.

DESCRIPTION OF PLATE XIII.

The Plate represents the appearance of a polished slab of the augen-gabbro of Karak-clews. The "eyes" are formed of diallage. The dark bands are formed mainly of green hornblende; the white bands, of the aggregate generally known as saussurite. The white spots seen in certain parts of the Plate represent an undetermined mineral which is almost constantly present in the Lizard gabbros. It appears in the glassy felspar of the comparatively unaltered rocks, and increases in amount as the felspar passes into the condition of saussurite. There is much greater detail in the dark bands than is represented in the Plate. The block is traversed by narrow veins which cut the planes of foliation at angles of about 15°.

II.—On the Ffynon Beuno Caves.

By Prof. T. McKenny Hughes, M.A., F.G.S.

MUCH interest has been recently aroused in the exploration of the caves of the Vale of Clwyd, partly by the enthusiasm of the principal promoter of the investigation, Dr. Hicks, but chiefly owing to the inferences he has drawn from the observations made. When reading the Report of the British Association Committee for the Exploration, of which he was Secretary, he assumed the entire responsibility of those theoretical deductions. In these, however, he was supported by all the speakers who followed him on the subject, including the other members of the Committee excepting myself. He had previously anticipated the report by the announcement in *Nature* of his discovery of Pre-Glacial Man in the Vale of Clwyd. I therefore ask leave briefly to state my reasons for differing from his conclusions.

First, I recognize in the Vale of Clwyd four drifts which must be distinguished in this inquiry.

1. *The Arenig Drift,* which contains fragments from the W. and S. only, and which is the only true glacial deposit in the Vale of Clwyd, as there is no evidence of any glacier having ever come down the Vale.

2. *The Clwydian Drift.* — (*A*) a marine deposit due to the submergence which followed the age of extreme glaciation and containing, in addition to the re-sorted débris of the older drift, flint and fragments of granite and other north-country rocks. (*B*) the still further winnowed débris belonging to the age of emergence.

I am not very clear about the possibility of often distinguishing

between *A* and *B*; but there is a good deal of evidence in some localities.

3. The almost universal covering of re-sorted drifts and rain-wash, the results of subaerial denudation since the submergence.

If the mouth of a cave is said to be blocked by drift, we must be careful to enquire *what drift*, before we take it as a measure of the age of the cave-deposits.

There are some other points also which must be attended to. We must distinguish between the age of the caves and that of the cave-deposits. So many changes and modifications go on in some cases that their history and that of their contents cannot always be read, even during the most careful excavation.

There are in the Vale of Clwyd many caves representing subterranean channels through which the water running off the Silurian hills around, drops into fissures on reaching the Mountain Limestone, and finds its way to lower ground. Some of these caves are being formed now, and in some of them mud still settles after floods. Bones and stones still get washed down into the fissures which feed the cave, and these fissures are often enlarged or new ones opened where the moisture can get access to the rock. So of course the wash from the superficial deposits forms a large item in the later packing of a cave. In the Plas Heaton cave, which I explored with the late Mr. John Heaton, I found pieces of magnums in the cave-earth which were beyond where man could creep when I first knew the cave. The other end of that cave was blocked with clay, full of glaciated boulders: a mass undistinguishable from the clayey Clwydian drift. In the Pontnewydd cave, on the other hand, I found felstone implements and flint flakes not far from the surface near the mouth of the cave.

The limestone on both sides of the little ravine which runs down into the Vale of Clwyd at Ffynon Beuno, near the village of Tremeirchion, is perforated with numerous caves and cavernous places. They very frequently coincide more or less with lines of joint and small faults, along which calc-spar and various minerals suggested the possibility of ore. One precipitous face on the north side had an open cave large enough to furnish a shelter for cattle. In this trial-holes had been dug, and the cave-earth had been moved in places. The fragments of bone lying about suggested that the Sheep and Fox of to-day had once been represented by the Stag and Hyæna, and I suggested to the Chester Natural Science Society to open these caves, and foretold the probability of our obtaining the remains of Primeval Man. The following year Dr. Hicks excavated near the mouth of the cave, and obtained such interesting results, that he obtained a grant from the Royal Society, and afterwards from the British Association, to enable him to carry on the explorations, the results of which he has laid before the Association and other scientific societies. A few feet higher up the rock-face is another opening belonging to the same drainage-system. This also has been excavated by Dr. Hicks and Mr. Luxmoore, and it has been supposed that in it evidence has been obtained of the residence of

Man in that locality before the close of the Glacial period. Now the evidence is briefly this. This cave was filled with a clayey or sandy deposit, containing bones of the extinct Mammalia and boulders of various material. On excavating this deposit, the other or N.W. mouth of the cave was found to be concealed under a deep deposit of sand and sandy clay full of boulders under which, beyond the overhanging ledge of rock, were fragments of bone similar to those occurring in the cave, and, close to the mouth of the cave, a flint flake was found imbedded in red sandy clay, and associated with the teeth of Rhinoceros, etc.

Now what are the points? Was this drift No. 1, or No. 2 *A*, or No. 2 *B*, or No. 3, of our classification given above on p. 489?

Certainly not No. 1, as it contains north country granites, etc., which came into that district for the first time with the submergence. Therefore the drift must belong to No. 2 or 3, and these are Post-Glacial.

We have next to ask whether it is probable that the drift which lies on the bones outside the cave can be the drift laid down in the great Post-Glacial submergence, and the cave-deposits belong to a time anterior to that submergence. Let those accept this view who can imagine that the waves dashing against a precipitous rock exposed to the N.W. winds would not have swept such loose débris into the deep fjord below, and swilled out the cave quite clean in every tide.

I strongly suspect, though I cannot quite prove it, that the mass which overlaps the mouth of the cave belongs to No. 3 drift—I know of no part of the marginal drift at all like it and it differs much from any of that seen in the central portion of the Vale. Neither the beds in the cave nor those outside it look like a shore-deposit.

Again, no notice has been taken of the old fence which runs along the slope up to the precipice, about 20 feet from the entrance to the upper cave, where the flake was found. The soil has accumulated against the upper side of this fence until there is now a drop of eight feet to the level of the ground on the lower side of the fence. This tells of a pretty rapid working down the slope of all the soft surface drift. I think I recognize in some of the stones out of the so-called Glacial drift that blocked the cave the traces of agricultural implements as well as true Glacial striæ. Yet no distinction has been made between a newer superficial remanié drift and an older true Clwydian drift. And rightly so I believe; it is all remanié as far as yet explored.

Next as to the flake. It occurred in a sandy clay such as would be derived from the wash of the Clwydian drift mixed with the unctuous irony residuum of the decomposed limestone, and not in a regular layer or laminated deposit like that found more commonly in the central portion of the cave. It was found in a kind of horizontal fissure after an overhanging corner of limestone had been removed from close above it. Inside of and more especially at the mouth of most caves there is a breccia consisting of angular frag-

ments which have fallen from the rock while the cave was exposed to changes in the amount of moisture and temperature. The interstices get filled with inwashed clay. Sometimes the mouth is blocked by a perfect barricade of large blocks which have fallen from the face of the rock where most exposed. This was very conspicuous at Plas Heaton. At Ffynon Beuno, however, the fragments at the upper entrance were generally small. It was among these that the flake was found.

I do not, however, attach so much importance as some do to the questions connected with the flake. It would be difficult enough to prove that the group of animals found in the Ffynon Beuno caves were Pre-Glacial, for they are the animals commonly found associated with Palæolithic Man, and do not even include what we are accustomed to consider the oldest forms amongst them.

To sum up. Firstly, the deposits of the Ffynon Beuno caves cannot have been formed before the submergence, because rocks first brought into the district during the submergence are found among them. They cannot have been formed during the submergence, because the bone deposits at the mouth would have been washed away, and the deposits inside would have shown some evidence of sea-sorting. So they must belong to an age later than the submergence, and *à fortiori* later than the Glacial age. Secondly, the blocking of the upper entrance seems to have taken place gradually; and while it was going on, drift material was washed into the cave, and various objects got into the crevices of the broken limestone talus; but the lower end of the cave, next the precipice, remained open. Thirdly, the palæontological evidence is against the Pre-Glacial age of the deposit, as the bones belong to the newer group of animals found elsewhere in undoubtedly Post-Glacial river deposits.

III.—On a Facetted and Striated Pebble from the Olive Group Conglomerate of Cliel Hill in the Salt Range of the Punjab, India.[1]

By A. B. Wynne, F.G.S.

AMONGST others found by Dr. H. K. Warth, the particular pebble referred to was picked up by its discoverer on the 10th of June, 1886, in about lat. 32° 48′ N. and long. 73° 15′ E. Its size is $3\frac{1}{4}$ inches by $2\frac{1}{4}$ by 2 inches; and its weight is $10\frac{1}{4}$ oz. The material is felsitic rock, the colour reddish-brown, and its density = 2·608 (that of albite being 2·59—2·64).

The age of the Olive Group, from which the pebble came, is pre-Tertiary and probably later Secondary, but has even been assumed as Carboniferous, upon what the author believed to be inconclusive evidence.[2]

The pebble itself is smoothed, polished, and striated upon twelve different surfaces. Of these about six are perfectly flat, others less

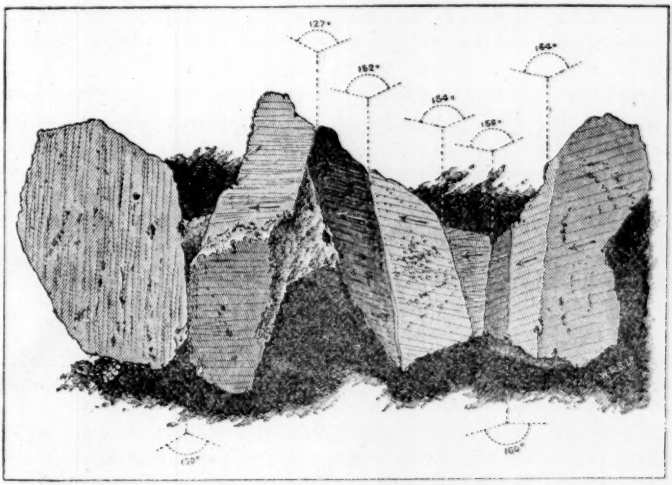
[1] Paper read before the British Association, Birmingham.

[2] See Geol. Mag. Decade III. Vol. III. p. 232, 1886. The specimen itself is in the Museum of the Department of Science and Art in Dublin, and the enlarged photograph referred to was presented to the Geological Society, London.

even. On the largest surface the striation is fine, nearly in the direction of the longest axis of the pebble, on other surfaces they cross this direction at various acute angles, ranging from 5° to 25° and upwards.

An enlarged photograph of the pebble, showing its principal face and the well-marked striation of this, was exhibited. Some of the planes show small cavities, once apparently filled by crystals of pyrites, which, being dislodged and forced, always in similar parallel directions, became the graving-tools by which the stone was scored.

Projection of some of the faces of the pebble, by Prof. O'Reilly, Rl. Col. Sc. Dub. Reduced to two-thirds nat. size.



In this figure the pebble's principal face is shown to the left, and the others consecutively in contact in one direction as they adjoin each other on the specimen; the figures denoting the angle between each face.

From the position of a group of the facets, all contiguous and of unequal size, together with the slight difference of direction in their striation, it appears that this pebble made about a half revolution nearly around its major axis by six separate stages, being ground and polished at each stage to a degree closely simulating the most artificial accuracy.

The conditions which would permit of this result become a question for consideration. Supposing the pebble to have been grasped by ice, whatever its bulk, having an effective hold of but two inches; this being the utmost amount to which it could have been imbedded while any of these surfaces was exposed: will this account for the sculpture of the specimens?

Other questions which the pebble suggested were:—

1. How it became so frequently shifted in the matrix which produced the resistance that not alone was one-half of it subjected

to grinding processes from different directions, but its exactly opposite side was even more perfectly smoothed and marked than any other?

2. On the supposition that ice was an agent in the case, does the difference in the angles of the faces and the direction of the striation afford a measure of the plasticity of ice?

3. What form of ice agency may have been the originating cause, shore, ground, floe, floating or glacier ice?

4. Was the pebble continuously frozen in or free at times, and was it imbedded in a moving ice mass, or held so as to oppose such a force?

5. Could any other agency than that of ice have produced the result?

These questions were laid before the Section, in order to obtain general and valuable opinions, or elicit suggestions upon a point of great interest, in any case, but particularly, as bearing upon the existence of an earlier glacial period than that so well known to modern geologists; and one which has left its trace in regions where glaciers cannot now possibly exist, though these are found, at a distance, in the higher regions of the Himalayan chain; but even there entirely dissociated from direct connexion with any portion of the Salt Range Geological Series.

IV.—Notes on a Smoothed and Striated Boulder from a Pre-tertiary Deposit in the Punjab Salt Range.[1]

By Dr. W. T. Blanford, F.R.S., Sec. Geol. Soc.

THE block of stone in question, like another exhibited by Mr. A. B. Wynne, was obtained by Dr. Warth, at Chel Hill, in the Punjab Salt Range. This specimen was sent by Dr. Warth to Mr. H. B. Medlicott, Director of the Geological Survey of India, who forwarded it to the present writer, in the hope of learning the views of those who have most experience of similarly marked boulders, and of ascertaining whether the peculiar characters of the present specimen are due to any particular form of ice action or to any other agency.

The stone consists of a purplish-brown porphyry, apparently an altered felspar-porphyry. This rock is known to occur in Rajputana, near Jodhpur, between 300 and 400 miles south of the Salt Range, and belongs to a group of beds supposed to be Archæan, and known by the name of Maláni. These rocks may occur nearer to the Salt Range, but the intervening country is imperfectly known, and is much covered with river alluvium and blown sand.

The boulder exhibited measures $7\frac{1}{4}'' \times 6'' \times 3\frac{1}{4}''$. It is subangular, the two principal surfaces are plane, smooth, finely striated, opposite to each other, and nearly but not quite parallel. Each of these surfaces is bevelled off on one edge by a number of smaller facets, meeting the principal surface and each other at very obtuse angles. Besides the larger plane surface there are on one side five smaller smoothed facets, and on the other two, but one in each case is ill-marked, the angle at which it meets the next surface being so obtuse as to be with difficulty recognized. All the smoothed surfaces on one side are striated in the same direction; those on the other side are striated

[1] A paper read before the British Association, Birmingham.

similarly to each other, but diversely to those on the opposite surface of the block. Those surfaces of the block that are not smoothed are somewhat rounded.

The bed from which the block was obtained is said to abound in similar boulders, but they are not in general smoothed or striated. They are found in an olive-coloured matrix of fine silt. The bed has been described by Mr. Wynne, Dr. Waagen, and Mr. R. Oldham, and a general *résumé* of its geological relations was given in the Quart. Journ. Geol. Soc. for the present year, p. 254. The strata immediately overlying are marine, and contain fossils that are either Palæocene or very high Cretaceous, but the age of the boulder bed itself is somewhat doubtful. The occurrence of large boulders in a fine silt appears to indicate glacial conditions as in the Talchir beds of India, of which there is a possibility that this Salt Range bed may be a representative, although most of those who have examined the ground think it to belong to a much later geological period, and associate it with the overlying Upper Cretaceous or Palæocene strata.

V.—On Fossil Flowering or Phanerogamous Plants.

By J. S. Gardner, F.L.S., F.G.S.[1]

OUR attention has been devoted exclusively this year to the fossil flowering or phanerogamous plants. The results of our researches point to the conclusion that while that section known as Gymnospermous, to which the Coniferæ belong, is of the highest antiquity, being almost coeval with the first definite remains of plants in the Palæozoic age, there are no Angiospermous plants in British rocks of greater antiquity than the Secondary period, if we except the problematic plant known as *Spirangium*. Even down to so late as the Lias we have been unable to ascertain that any indisputable Angiosperm has been discovered within our area, for we are led to the conclusion that the supposed Monocotyledons from the Rhætics, near Bristol, hitherto referred to the family of Pond-weeds under the name *Najadita*, are really cryptogamic plants of the moss tribe, closely allied to the river moss *Fontinalis*. This group had not previously been found fossil, and, so far as it goes, would indicate rather a temperate climate. It is important to notice that these conclusions are shared by such high authorities on fossil plants as Prof. Williamson, Mr. Carruthers, and by all botanists who have examined them, as well as Mr. Brodie, the possessor of the specimens. The *Lilia*, *Bensonia*, and other supposed Monocotyledons of similar age are very imperfectly preserved and, doubtless referable to Cycads, a family which abounded then.

We have examined a large number of specimens of the anomalous Jurassic plant described by Carruthers as *Williamsonia*. It is well known that Prof. Williamson, in whose possession or charge a number of the finest specimens remain, has devoted a considerable amount

[1] Being the Second Report of the Committee, consisting of Mr. W. T. Blanford, Professor J. W. Judd, and Messrs. W. Carruthers, H. Woodward, and J. S. Gardner (Secretary), appointed by the British Association for the purpose of reporting on the Fossil Plants of the Tertiary and Secondary Beds of the United Kingdom.

of attention to them, without, however, feeling justified in coming to any very definite conclusion as to their true position in the vegetable world. De Saporta, on the other hand, has found more perfectly preserved specimens in France, and has no hesitation whatever in referring them to the group of *Pandanaceæ*. Though there are still many difficulties in the way, our own examination of the specimens in London, Manchester, Cambridge, and elsewhere, tends to confirm Saporta's view so far as that there do appear to be vestiges, in some cases at least, of lignitic structure which may represent the areolæ or carpels. These rather minute cavities and the lignitic matter surrounding them fall away on exposure to the air, and only traces of them are visible. Should Saporta's contention be upheld, *Williamsonia* will be by far the most perfectly known of the Secondary Angiosperms, since all the organs of fructification and even of foliation are more or less known.

A still more definite Monocotyledon is the *Podocarya*, from the Inferior Oolite, originally figured by Buckland, and redescribed by Carruthers. Its resemblance to the fruit of *Williamsonia*, as interpreted by Saporta, is extremely striking, and on suggesting this to that author, he replied that he was in the act of preparing an important work on the very subject. The same work is to include an illustration of the most recent member of the group, obtained from the Grey Chalk of Dover, and which we thought advisable to communicate to him.

Next in point of age, among English Monocotyledons, to the *Podocarya* is the *Kaidacarpum*, from the Great Oolite, also described by Carruthers, and by him referred to the *Pandaneæ*. We have been able to ascertain that a second species, hitherto supposed to be of Cretaceous age, from the Potton Sands, is a derived fossil, and undoubtedly Jurassic. A third species was originally figured, without any reference in the letterpress as to its age or locality, by Lindley and Hutton as *Strobilites Bucklandi*, in their 'Fossil Flora,' vol. ii. p. 129, published between 1833–35, from a drawing made by Miss E. Benett for Dr. Buckland. In the first edition of Morris's 'Catalogue,' 1843, it is set down as from 'Gr. S. Wilts,' which cannot mean either Lower or Upper Greensand, the abbreviations for which are 'L. G. S.' and 'U. G. S.,' but which certainly looks like a misprint for 'Gr. O.,' the sign for Great Oolite. In the second edition of Morris, 1854, the locality is corrected to 'U. G. S. Wiltshire,' but it appears likely that the correction may have been made without ascertaining the facts *de novo*, for the only entry occurring in Miss Benett's 'Catalogue of the Organic Remains of Wiltshire,' published in 1831, that could possibly refer to this fossil, is a '*Cycadeoidea?*' from the Portland Beds, which occurs under the heading 'Woods' on p. 9. A journey to Newcastle with the object of examining the Hutton collection of fossil plants, where it seemed probable the specimen might be found, has been unsuccessful, and its present whereabouts is still unknown. We think, it however, far more likely to prove a Jurassic than a Cretaceous fossil if found, and the genus should not be included in lists of plants of the latter age.

The oldest Monocotyledons thus appear to be referable to the Pandaneæ, a group of plants distributed in widely distant and remote oceanic islands, whose fruits are still met with at sea in drifts of vegetable matter.

Next to these in antiquity are two very monocotyledonous-looking fragments from the Jurassic of Yorkshire, which have been fully described in the GEOLOGICAL MAGAZINE for May and August. The one is apparently an unopened palm-like spathe, and the other a jointed cane-like stem. Mr. Brodie possesses an undoubtedly monocotyledonous leaf fragment from the Purbeck of Swindon.

The *Aroïdeæ* have long been supposed to be a group of very high antiquity, but there are good reasons for believing that the supposed remains of aroïdeous plants from beneath the Tertiaries are, without exception, referable to other groups, and actually there are no known traces of them earlier than the Middle Eocene, when they become by no means uncommon.

In a similar manner the fruits once supposed to represent *palms* in the Palæozoic and Mesozoic rocks have been gradually removed or suppressed, and, unless the fragments of palm-like wood in the Gault at Folkestone are taken into account, there are no traces of palms in any of our Secondary strata. They, however, appear as low down in our Eocene as the Woolwich series.

We are not able to speak with certainty regarding the supposed liliaceous or *Dracæna*-like stems from the Wealden, so frequently mentioned by Mantell, since it is not easy now to identify the particular specimens referred to by him; but it is very probable that certain stems of *Endogenites* in the British Museum are those intended, in which case they are, of course, cycadeous. The Wealden has, indeed, so far yielded no trace whatever of any more highly organized plants than ferns and Gymnosperms, and this, when we consider that Monocotyledons were undoubtedly in existence, is a fact that should be of great significance to speculative geologists. The sediments must represent the deposits of the drainage system of a large area, for they are of vast extent and thickness, varied in character, and abounding in remains of trunks and stems, fruits and foliage of plants. In them, therefore, if anywhere, we might reasonably expect to find at least the traces of reed and rush, but the swamps seem to have been tenanted only by Equisetum and ferns, and the forests by Cycads and Conifers.

The same absence of Angiosperms, so far as British rocks are concerned, is continuous throughout the Neocomian and Gault, and it is only in the White Chalk that we meet with any indications of them, and these only take the form of a more than suspicious impression of a net-veined leaf, in the Jermyn Street Museum, and of some structureless bodies which were apparently some kind of fruit.

When, however, we turn to the gymnospermous section of Phanerogams, the records are very different. To refer here to the earlier Secondary Coniferæ and Cycadeæ would be quite beyond our province, and it is only those of the Cretaceous, as the last discoverable ancestors in our area of the Eocene flora, that are of immediate

interest. These belong, excluding Cycads, chiefly to the newest section of the Coniferæ, the Pine family. We are able to make the following contribution to our knowledge of these:

Pinites Andræi, Coemans. 'Flore fossile du Terrain Crétacé du Hainault,' 1866, p. 13, pl. v. fig. 1. Gault, Folkestone.

This specimen measures 5 centimetres in length and nearly 3c. in breadth, though something should be perhaps deducted for the compression undergone. When perfect, it was probably composed of 50 to 60 imbricated leathery scales, about half that number being visible on the exposed face. The substance of the scale seems to have been considerable, though the edges are thin; they are smooth even without striæ, and with the upper margin round to obtusely pointed. They are apparently variable in size.

The cone is of the same general type as *P. Andræi*, Coem., from the Gault of La Louvière, Hainault, though somewhat shorter, more oval, and with thinner and rounder scales. The form and general consistence of the scales, as well as their size, the number composing each whorl, and their disposition are, however, so similar that we think it better, in the case of so imperfect a specimen, to unite it rather than claim specific rank on account of distinctions that might largely disappear with more perfect specimens. If the assimilation is correct, the apex of the cone, as well as the base, would have been somewhat pointed. The cones are most abundant at La Louvière, more than 100 specimens having been collected; and they are stated to have been frequently curved and highly resinous. The specimen from Folkestone was found by us, being unique from that locality, and is now in the British Museum.

Pinites Valdensis, sp. nov., Wealden, Brook Point, Isle of Wight.

This fragment shows the presence in the Wealden flora of a Pine of the section *Strobus* with a cone composed of scales as numerous and thin as in any recent species. The cone was long, cylindrical, and tapering; the scales very numerous, permanent, imbricated, leathery, pointed, and lightly thickened at the apex, with entire margin, striated, and slightly keeled. It somewhat resembles *P. Dunkeri*, Carr., also of the Wealden, but is probably a distinct species. One specimen is in the York Museum, and another, in which all the scales are mutilated, is in the Woodwardian Museum. Both these, with several others, are from the Wealden of Brook, so that it appears to be by no means rare there. It is associated with *Cycadostrobus elegans*, Carr.[1]

Pinites Carruthersi, sp. nov. Wealden, Brook Point, Isle of Wight.

The fragment represents another long cylindrical cone with very numerous persistent leathery imbricated scales. It tapers like the one last described towards the base, the scales being much thicker, though thin at the edge, smooth, without keel, and with entire rounded margins. It resembles the Gault species *P. Andræi* in texture, but there were at least twice as many scales in each whorl, and these are much more imbricated. It also is quite distinct from *P. Dunkeri*, Carr.

[1] *Journ. of Bot.* vol. iv. pl. lvii. fig. 9.

It resembles *Cedrus Lennieri*, 'Sap. Veg. foss. de la Craie inférieure des Environs du Hâvre,' *Mém. de la Soc. Géol. de Normandie*, 1877, but is not apparently the same species.

Pinites cylindroides, sp. nov., Lower Greensand, Potton.

This is an almost perfectly cylindrical specimen, being very slightly thickened towards the base, 7 centimetres in length and 22 millim. in diameter, composed of about 96 scales, arranged in 12 rows from left to right, and eight rows from right to left, the arrangement thus being $\frac{8}{12}$. The scales are short and at right angles to the axis, with a smooth flat half-moon-shaped apophysis or scale-head, now gaping, but evidently imbricated before the seeds were shed. The scales become very small towards the base. The summit is abraded, exposing the end of a somewhat slender axis. Certain grooved lines on the sandy matrix between the scales show that the cone was furnished with foliaceous bracts, and the marks of a boring insect are visible. The specimen, which is quite distinct from any other fossil or recent cone, is singularly elongated and cylindrical, scarcely tapering at all from the base upward. It is fortunately in excellent condition, certainly not derived from any older bed, like so many of the Potton fossils, and is well cared for in the Woodwardian Museum.

Pinites Pottoniensis, sp. nov., Lower Greensand, Potton.

The fragment, though much mutilated, fortunately shows the characteristically winged seeds of *Pinus* in the most perfect manner, entirely removing any lingering doubt as to the occurrence of representatives of true *Pinus* as low down as the Neocomian. The scales were set at an acute angle with slightly thickened recurved apophyses, the form of which cannot clearly be made out, though they appear to have been narrow, keeled, and mucronate. It nearly resembles a type very common in the Eocene, and is of great interest in many ways. It also is in the Woodwardian Museum, and was obtained from the same formation.

Another specimen evidently represents a third species from the Wealden of Brook, with scales very closely resembling a common Barton and Bracklesham type, but its fragmentary condition scarcely renders it advisable to attach any specific name to it.

The accompanying list comprises all the British Cretaceous Coniferæ previously known up to the present date, though there is no doubt that many new and undescribed forms exist in collections.

List of British Cretaceous Coniferæ previously described.

Pinites Fittoni, Carr., Purbeck, Fitton, Geol. Trans. 2nd series, vol. iv. p. 230, pl. xxii. fig. 9. Dammarites, Ung. G. et Spec. Plant. foss. p. 384. Geol. Mag. Vol. III. p. 543.

P. Mantellii, Carr., Geol. I. of W. 2nd ed. p. 452, 3rd ed. p. 377, pl. xlii. ; and Carr. Gym. Fruits, Geol. Mag. Vol. III. p. 543, Pl. XXI. Fig. 3, Tilgate.

P. patens, Carr. id. p. 543, Pl. XXI. Fig. 4, Tilgate.

P. Dunkeri, Carr. id. p. 542, Pl. XXI. Fig. 1–2, Brook. Abietites, Mant. Geol. I. of Wight, 2nd ed. p. 452.

P. Sussexiensis, Carr. Zamia, Mant. Quart. Journ. Geol. Soc. vol. ii. p. 51, pl. 2, fig. 1 ; Zamites, Morris Cat. Zamiostrobus, Goepp. Ueber Schless. Gesellsch. 1844, p. 129 ; Pinites, Carr. Geol. Mag. Vol. III. p 541, Pl. XX. Figs. 5, 6.

Cedrus Leckenbyi, Carr. Pinites, Geol. Mag. Vol. VI. p. 2, Pl. I. Fig. 1-5, Shanklin.

P. elongatus, Endl. Synops. Conif. p. 286; Strobilites, Lind. and Hutt. Foss. Flora, vol. ii. p. 23, pl. 29.

C. Benstedi, Carr. Abies. Mant. Quart. Journ. Geol. Soc. vol. ii. p. 51, pl. ii. fig. 2, 1846. Pinites, Carr. Journ. Bot. Jan. 1867; Geol. Mag. Vol. III. p. 541; Abietites, Goepp. Foss. Conif. p. 217.

Abies oblonga, Lind. and Hutt. vol. ii. p. 155, pl. cxxxvii. Supposed to be from Greensand, near Lyme Regis; described by a misprint as from 'Dresent,' instead of 'present' shore. Elate, Unger, Syn. p. 199. Abietites, Goepp. Foss. Conif. p. 207. Pinites, Endl. Synops. Conif. p. 248; Carr. Geol. Mag. Vol. III. p. 541. (Professor Williamson is describing a magnificent specimen of this or an allied form).

Pinites gracilis, Carr. Gault, Folkestone, Geol. Mag. Vol. VI. p. 2, Pl. I. Fig. 9.

P. hexagonus, Carr. id.[1] Vol. VIII. p. 540, pl. XV.

Sequoiites Gardneri, Carr. id. Vol. VI. p. 2, Pl. I.

Sequoiites ovalis, Carr. id. Vol. VIII.

Sequoiites Woodwardii, Carr. Geol. Mag. Vol. III. p. 544, Pl. XXI. Fig. 11–16, Blackdown.

We have now dealt with the more highly-organized of our Mesozoic plants, and pass on to those of the Eocene.

Among the most interesting of recent discoveries is that of plant remains in a small sand-pit at Colden Common, between Bishopstoke and Winchester, the first locality in the Hampshire basin that has yielded any of Woolwich and Reading age. This was first communicated to us by Mr. Whitaker, who thought the leaves might prove to be of London Clay age. They are, in fact, actually included in its basement bed, and mingled with casts of marine shells and sharks' teeth, but the blocks of clay with leaves are derived, though other unfossiliferous clay-seams are *in situ*. If not of London Clay age, however, they are much nearer to it than the Reading flora, which occurs below the great mass of mottled clay, whilst these lie above it. The plants show in the main, as might be anticipated, an approach to the Alum Bay flora, which is still higher and above the London Clay; but whether these leaves are connected in any closer degree with the fruits of Sheppey than are those from Woolwich, Croydon, or Bromley, is a question which we have not as yet the data for answering. There are, at all events, no remains of Palms among them, and this, so far as it goes, is against the connection; but on the other hand the fruits of an *Alnus*, like that from Swale Cliff, abound. There is no large variety among the leaves, the majority being large and simple, but with highly serrate margins, and the species will not be found to exceed 12 or 14 in number, including *Platanus*, which is rare.

Though we have continued to collect at Reading, we have been unable so far to determine any new species. The assemblage of fruits at Sheppey, on the other hand, becomes of increasing interest, and has proved unexpectedly rich in Palms, many of them apparently identical with existing species which are now found growing in the remotest regions.

Besides the large variety of Nipas, which are still met with in enormous abundance among the seed-vessels of the New Guinea drift, we have seeds indistinguishable from *Verschaffeltia splendida*,

[1] A far larger specimen than that originally described, 8 inches long by $1\frac{3}{4}$ inches in diameter, has since been found.

endemic to the Seychelles, from *Sabal Blackburniana* of the Bermudas, from a *Desmoncus*, an *Areca*, a *Monodora*, and probably of many, certainly of some other palms. When we consider that probably many of the kinds of palm fruits would sink at once, we realize how great an assemblage of this magnificent family is indicated by the Sheppey drift.

The difficulties we fear of determining anything but a fraction of the Sheppey fruits must prove insurmountable. Their outer coats are for the most part destroyed, and some part of their inner structure, nearly always quite different in form from that which is external, is revealed. Botanists have been able to determine but few of the drifted fruits brought home by the *Challenger*, though these are more perfect and of living species belonging to definite and known floras.

The Bournemouth cliffs continue to furnish fresh forms, though the leaf-beds are becoming more and more difficult of access. We have especially enriched the series of *Smilaceæ*, and a complete account of them has been presented to the Linnean Society. The series now obtained falls little short of a hundred specimens, and is by far the richest of fossil Smilaceæ, perhaps of any family, ever brought together. Such a material has enabled us to reduce the number of distinct species to no more than five, most of which are represented by foliage in all stages of development, from the largest leaves measuring several inches, down to quite minute leaves from near the extreme growing points. The necessity for such extensive series when dealing with fossil leaves may not at once be apparent, but the President of the Linnean Society expressed the opinion at the meeting, that out of less material, not five, but five-and-twenty species might have been made.

The leaves of Smilaceæ are highly characteristic, and can be determined with a large degree of certainty; but it is quite improbable that such will be the case with very many of the families of Dicotyledons. There is, indeed, little hope that more than a very few can be determined with anything like the precision required for botanical purposes, unless we can call in aid the fruits or some other organs. Thus if we may base a conclusion upon the large number of the characteristic bracts, which envelope the seed in a section of *Flemingia* that are met with in the Bournemouth flora, the leaves of that genus should be far from uncommon, and they should also be found in the Swiss Oligocene, yet no species of *Flemingia* has ever been recorded from the Tertiaries. The leaves, however, may be sought for among the supposed species of *Populus* and *Carpinus*.

Fortunately fruits and even flowers are comparatively abundant at Bournemouth, and we consequently anticipate little difficulty in determining leaves belonging to such easily distinguishable fruits as *Alnus, Tilia, Acer, Carpinus*, the *Leguminosæ*, and many others, but the residuum with indeterminable fruits, or fruits that will not float, may be very large. We are thus brought to the question, whether any value beyond that of mere landmarks, or aids to the correlation of rocks, can be attached to the determinations of fossil dicotyledonous leaves arrived at when fruits are absent. Nearly every Tertiary and

even many Cretaceous floras are said to comprise *Quercus*, and *Fagus*, and *Corylus*, to select these as typical examples. Now we very much doubt whether the fruits of these genera have been met with in any strata older than the Upper Miocene, we might almost say the Pliocene; whilst in the latter the fruits of at least two of them are very far from uncommon. Fossil hazel-nuts are well known to abound in forest beds such as the one at Brook, in the Isle of Wight, and at Carrickfergus. It does appear to us that it would have been wiser and more consistent, when arriving at these determinations, to have taken the absence of fruits into account, when these were such as would naturally have been preserved. The large proportion of fossil dicotyledonous leaves that have been referred without any hesitation to living genera must strike every one, in comparison with the relatively few associated fruits that have been determined otherwise than as Carpolithes—a name which is a confession of failure. It will thus be seen that in our opinion the fossil Dicotyledons of our own Eocene must be dealt with in a manner different from that pursued by the majority of foreign writers on kindred subjects, and that a revision of much of their work is urgently needed.

To resume our immediate subject, we have nothing new to record of the Bracklesham flora except that Mr. Elwes, in excavating in the New Forest, met with Nipadites in some abundance, and a specimen he still has proves the species to be the same as that from Bracklesham Bay, and entirely different from that which forms a conspicuous zone in the marine series of the Bournemouth group.

At Barton, on the other hand, we have been able to procure nearly a dozen pine-cones, hitherto a great desideratum, from the Highcliff beds, which go far to prove that there is only one variety there, indistinguishable from the *Pinus Dixoni* of Bracklesham. Along with these we have branches of apparently the Bournemouth *Araucaria*, and an important and entirely new fruit, fortunately represented by many specimens, which permit us to examine the details of their structure. These consist of twigs on which are seated in some profusion clusters of numerous sessile woody pericarps with deeply laciniate margin, giving the fruit when closed the appearance of a large burr. These inclose a nut or seed, rather smaller, but otherwise resembling that of a cucumber. There has not yet been time to make the researches necessary to come to a conclusion regarding it, and Mr. Carruthers and other botanists who have seen the specimens are unable offhand to pronounce upon its affinities. A rather large fossil plant from the same locality has recently been lent us by the Council of the Hartley Institute, and altogether the plants from this horizon, hitherto very meagrely represented, bid fair to take an important position. On the other hand, the Hordwell end of the same section, though twice visited since our last report, has furnished nothing new.

We have fortunately met with a few very distinctly marked leaves from the Middle Headon of Headon Hill, preserved in the York Museum, which with those previously obtained from the Lower Headon of Hordwell, help to bridge-over one of the few gaps in our really surprisingly complete succession of Eocene floras.

We have continued to investigate the great series of plant remains so assiduously collected by Mr. A'Court Smith, and with this object have visited Gurnet Bay, as well as receiving several packages of fossils from thence. While lamenting that they are of so fragmentary a nature, we cannot overlook their importance as almost the last representatives of the great series of floras which maintained themselves in our area throughout the Eocene time. As an illustration of their value, we may instance the fact that while anything like true grasses seem to be wholly wanting in the previous floras, there are many more or less definite indications of them in this. We have reason to hope that renewed working in the still younger beds of Hempstead may lead to further discoveries, for, besides the better known plants described by Heer, pine-cones and a fine aroïdeous fruit have been obtained from them.

NOTICES OF MEMOIRS.

Papers read before the British Association for the Advancement of Science, Birmingham, September, 1886, Section C (Geology).

I.—On Canadian Examples of Supposed Fossil Algæ. By Sir William Dawson, LL.D., F.R.S.

MARKINGS of various kinds on the surfaces of stratified rocks have been loosely referred to Algæ or Fucoids under a great variety of names; and when recently the attempt was made in Europe more critically to define and classify these objects, a great divergence of opinion developed itself, of which the recent memoirs of Nathorst, Williamson, Saporta, and Delgado may be taken as examples.

The author, acting on a suggestion of Sir R. Owen, was enabled in 1862 and 1864, by the study of the footprints of the recent *Limulus polyphemus*, to show that not merely the impressions known as *Protichnites* and *Climactichnites*, but also the supposed fucoids of the genera *Rusophycus*, *Arthrophycus*, and *Cruziana* are really tracks of Crustacea, and not improbably of Trilobites and Limuloids.[1] He had subsequently applied similar explanations to a variety of other impressions found on Palæozoic rocks.[2] The object of the present paper was to illustrate by a number of additional examples the same conclusions, and especially to support the recent results of Nathorst and Williamson.

Rusichnites, *Arthrichnites*, *Chrossochorda*, and *Cruziana*, with other forms of so-called *Bilobites*, are closely allied to each other, and are explicable by reference to the impressions left by the swimming and walking feet of Limulus, and by the burrows of that animal. They pass into Protichnites by such forms as the *P. Davisii* of Williamson, and *Saerichnites* of Billings, and *Diplichnites* of the author. They are connected with the worm tracks of the genus *Nereites* by specimens of *Arthrichnites*, in which the central furrow becomes obsolete, and by the genus *Gyrichnites* of Whiteaves.[3]

[1] "On Footprints of Limulus," Canad. Nat. 1862. "On the Fossils of the Genus *Rusophycus*," *Ibid.* 1864.

[2] "On Footprints and Impressions of Aquatic Animals," Am. Journ. of Science.

[3] Trans. Royal Society of Canada, 1883.

The tuberculated impressions known as *Phymatoderma* and *Caulerpites* may, as Zeiller has shown, be made by the burrowing of the mole-cricket, and fine examples occurring in the Clinton formation of Canada are probably the work of Crustacea. It is probable, however, that some of the later forms referred to these genera are really Algæ related to *Caulerpa*, or even branches of Conifers of the genus *Brachyphyllum*.

Nereites and *Planulites* are tracks and burrows of worms, with or without marks of setæ, and some of the markings referred to *Palæochorda*, *Palæophycus*, and *Scolithus* have their places here. Many examples highly illustrative of the manner of formation of these impressions are afforded by Canadian rocks.

Branching forms referred to *Licrophycus* of Billings, and some of those referred to *Buthotrephis*, Hall, as well as radiating markings referable to *Scotolithus*, *Gyrophyllites*, and *Asterophycus*, are explained by the branching burrows of worms illustrated by Nathorst and the author. *Astropolithon*, of the Canadian Cambrian, seems to be something organic, but of what nature is uncertain.

Rhabdichnites and *Eophyton* belong to impressions explicable by the trails of drifting seaweeds, the tail-markings of Crustacea, and the ruts ploughed by bivalve molluscs.

Dendrophycus, *Dictyolites*, some species of *Delesserites*, *Aristophycus*, and other branching and frond-like forms, were shown to be referable to rill-marks, of which many fine forms occurs in the Carboniferous of Nova Scotia, and also on the recent mud-flats of the Bay of Fundy.

The genus *Spirophyton*, properly so called, is certainly of vegetable origin, but many markings of water action, fin-marks, etc., have been confounded with these so-called 'Cauda-galli fucoids.'

On the other hand, some species of *Palæophycus*, *Buthotrephis* and *Sphenothallus* were shown to be true Algæ, by their forms and the evidence of organic matter, and *Haliserites*, *Barrandeina*, and *Nematophycus* were shown to include plants of much higher organization than the Algæ. With reference to the latter, it was held that the form to which the name *Prototaxites* had been given was really a land plant growing on the borders of the sea, and producing seeds fitted for flotation. On the other hand, certain forms to which he had given the name *Nematoxylon* were allied to Algæ in their structure, and may have been of aquatic habit; very perfectly preserved specimens of these last had been recently found, and had thrown new light on their structure.

The author proposed to apply to all these problematical plants, having a tissue of vertical and horizontal tubes, the general name *Nematophyteæ* or *Nematophyton*.

The paper referred to the history of opinion on these objects and the bibliography of the subject; but this, as well as detailed descriptions, are omitted in this abstract.

II.—On the Relations of the Geology of the Arctic and Atlantic Basins. By Sir J. William Dawson, LL.D., F.R.S.

THE paper relates to the evidence of the specimens brought from the Arctic seas bearing on the existence of an ancient line of Laurentian Huronian, and other Pre-Cambrian rocks; of the extension of the marine fauna of the Atlantic and the American continental plateau

into the Arctic, and of the correspondences of the Cretaceous, Tertiary, and Pleistocene of the Arctic Basin with those of America, and the bearing of these facts on questions of palæogeography.

III.—On the Rocky Mountains, with special reference to that part of the Range between the 49th Parallel and Head-waters of the Red Deer River. By George M. Dawson, D.Sc., F.G.S., etc., Assistant-Director, Geological Survey of Canada.

THE term "Rocky Mountains" is frequently applied in a loose way to the whole mountainous belt which borders the west side of the North American continent. This mountainous belt, is, however, preferably called the Cordillera region, and includes a great number of mountain systems or ranges, which on the 40th parallel have a breadth of not less than 700 miles. Nearly coincident with the 49th parallel, however, a change in the general character of the Cordillera region occurs. It becomes comparatively strict and narrow, and runs to the 56th parallel or beyond with an average width of about 400 miles only. This portion of the western mountain region comprises the greater part of the province of British Columbia. It consists of four main ranges, or, more correctly, systems of mountains, each including a number of component ranges. These mountain systems are, from east to west:—(1) The Rocky Mountains proper. (2) Mountains which may be classed together as the Gold Ranges. (3) The system of the Coast Ranges of British Columbia, sometimes improperly named the Cascade Ranges. (4) A mountain system which in its unsubmerged portions constitutes Vancouver and the Queen Charlotte Islands.

The present paper refers to the Rocky Mountains proper. This system, between the 49th and 53rd parallels, has an average width of about 60 miles, which, in the vicinity of the Peace River, on the 56th parallel, decreases to about 40 miles. It is bounded to the east by the Great Plains, which break into a series of foot-hills along its base; to the west by a remarkably straight and definite valley occupied by portions of the Columbia, Kootanie and other rivers.

Since the early part of the century the trade of the fur companies has traversed this range, chiefly by the Athabasca and Peace River Passes, but till the explorations effected by the expedition under Capt. Palliser in 1858-59 nothing was known in detail of the structure of the range. At the inception of explorations for the Canadian Pacific Railway, Palliser's map was still the only one on which any reliance could be placed, and it applied merely to the portion of the range south of the Athabasca Pass. During the progress of the railway explorations a number of passes were examined, and in 1883 and 1884 that part of the range between the 49th parallel and latitude 51° 30″ was explored and mapped in some detail in connection with the work of the Canadian Geological Survey by myself and assistants.

Access to this, the southern portion of the Rocky Mountains within Canadian territory, being now readily obtained by the railway, its mineral and other resources are receiving attention, while the magnificent alpine scenery which it affords is beginning to attract the attention of tourists and other travellers.

The results of the reconnaissance work so far accomplished are

presented in the form of a preliminary map, accompanied by descriptions of routes and passes, and remarks on the main orographic features of the range.[1]

IV.—The Anorthosite Rocks of Canada. By Frank D. Adams, Geological Survey of Canada.

THIS series of rocks has also been called the Upper Laurentian or Norian series. The name anorthosite is perhaps preferable, as it refers to their distinguishing characteristic as compared with the orthoclase rocks of the Lower Laurentian, viz. the predominance in them of plagioclase or anorthose felspar. These rocks form detached areas in the great Laurentian districts, and bear a strong resemblance in part to the gabbros and gabbro-diorites of Scandinavia, and in part to the labradorite rock of the same country. It is, however, by no means certain that the rocks of the two countries are of the same age. At least nine of these areas are now known to exist in Canada, and there is also one in the State of New York. In addition to plagioclase, which generally predominates largely, these rocks contain rhombic and monoclinic pyroxenes (including augite, diallage, hypersthene, and probably enstatite), olivine, magnesia, mica, spinel (including both pleonaste and picotite), garnet, iron-ores, pyrite, and apatite. Orthoclase is seldom or never found, except in veins cutting the anorthosite. The hornblende, mica, and pyroxenes are intimately associated and often intergrown, all of them sometimes being found in the same thin section. Garnet occurs sparingly, and generally near the contact of the anorthosite with the gneiss. When the olivine comes against plagioclase, it is always bounded by a double concentric zone, the outer zone consisting of hornblende, and the inner, or that next to the olivine, consisting of a pyroxene. While the iron-ores associated with the Lower Laurentian gneisses are generally free from titanium, those associated with the anorthosite rocks are always highly titaniferous; a fact which makes the study of these rocks a matter of considerable economic interest. The anorthosite varies a good deal in composition, some areas, for instance, being rich in olivine, while others are destitute of that mineral, and different portions of even the same area often showing wide differences in this respect. The rock also shows a good deal of variation in structure. It is rarely quite massive, frequently well foliated, but usually consists of a rather coarsely crystalline groundmass, through which are scattered irregular strings and masses composed of iron-ore, bisilicates, and mica, as well as larger porphyritic crystals of plagioclase. Even when it is tolerably constant in composition, there is generally a great variation in size of grain, coarse and fine alternating in rude bands or rounded masses. In the case of some of the areas there can be but little doubt that the anorthosite is eruptive, in others, however, it seems to be interstratified with the Laurentian gneiss, and in one of them to merge imperceptibly into it. The original relations of the rocks are, of course, much obscured by the effects of subsequent heat and pressure. The evidence at present, however, seems to indicate that these anorthosites are the result of some kind of extravasation, which in those early times corresponded to what in modern times we call volcanic eruption.

[1] See Reports and Maps Geological Survey of Canada.

V.—Notes on the Crystalline Schists of some parts of Ireland. By C. Callaway, D.Sc., M.A., F.G.S.

THE author gives a summary of results obtained by a preliminary survey of the principal areas of Irish metamorphic rocks, viz.—

1. Donegal, including parts of the adjacent counties of Londonderry and Tyrone.

2. Connemara, extending the term to cover the region lying between Westport, co. Mayo, and the granitic mass west of the town of Galway.

3. The south-eastern corner of the county of Wexford.

In each of these areas the following facts were observed:—

(*a*) A series of hypometamorphic rocks, consisting typically of fine-grained schists, altered grits, and quartzites. A clastic structure is more or less distinct in the three areas, but is least evident in Connemara.

(*b*) A group of highly crystalline schists, displaying no trace of an original sedimentary origin, dipping as if it passed below the hypometamorphic rocks. At Wexford there are true gneisses. In Connemara the rocks are less felspathic, the chief types being quartzose gneiss, quartz-schist, mica-schist, hornblende-schist, quartzite, and crystalline limestone. This description will also apply to Donegal.

(*c*) Granite, underlying (*b*), and in Connemara and Donegal clearly intrusive.

The author urges that this analogy is not due to the metamorphic action of the granite; for—

1. The mineral characters apparent in the schists adjacent to the granite are uniformly distributed through the lower series from bottom to top.

2. The evidence collected is hostile to the view that this lower series ever graduates into the upper.

It is concluded that the balance of proof is in favour of the Archæan age of the bulk of the Irish schists.

1. In the Wexford district the schists are thrown against Cambrian and Ordovician rocks by faults, and do not pass into them in the localities alleged by the Irish Survey.

2. In Connemara conglomerates of Llandovery age contain large rounded fragments, not only of the older schistose series, but also of its intrusive igneous rocks.

3. In the Ulster region the metamorphic area is separated from the Ordovician rocks of Pomeroy by a ridge of granite and diorite three miles in breadth.

The lithological analogies between the Irish schists and the Archæan rocks of Anglesey and other British metamorphic districts are also of weight in the argument.

VI.—On the Discovery of Fossil Fish in the New Red Sandstone (Upper Keuper) in Warwickshire. By the Rev. P. B. Brodie, M.A., F.G.S.

THE author observed that, considering the thickness and extent of the New Red Sandstone in Great Britain, the paucity and rarity of fossils was remarkable, especially when compared with the abundant fauna and flora of the Trias in Europe. In a field so comparatively

barren any addition, therefore, to either is interesting to the palæontologist. Many years ago the author discovered a ganoid fish—the last apparently of the genus *Palæoniscus superstes*—figured and described by the late Sir Philip Egerton (Journ. Geol. Soc. vol. xiv. p. 164) in the Upper Keuper at Rowington (six miles north-west of Warwick); and he now records another discovery of several small fish near there, probably *Semionotus*—at present in Dr. Traquair's hands—which is the first time this genus has been recorded from the British Trias. The remains of small Cestracionts are not unfrequent in one particular band of sandstone in Warwickshire and Worcestershire, with occasional footprints in the former county of *Labyrinthodon*. Ganoid fish are so rare that these above named are, as far as the author is aware, the only ones known, with one exception, which cannot be secured, in the Upper Keuper; the curious *Dipteronotus* having been found in the Lower Keuper (waterstones) at Bromsgrove, in Worcestershire. The author gave a section of the quarry containing the fossils above referred to, and stated that he considered that the New Red Sandstone in Warwickshire, as the Rev. J. Mello has adopted in Cheshire, might fairly and advantageously be divided into Upper and Lower Keuper, the two series of sandstones being different lithologically, and being separated by a considerable thickness of red marl, the lower sandstones being especially characterized by remains of *Labyrinthodon* and other peculiar reptiles, a fine and unique collection being preserved in the Warwick Museum.

VII.—On the Range and Extent and Fossils of the Rhætic Formation in Warwickshire. By the Rev. P. B. Brodie, M.A., F.G.S.

THE author in this paper first gives an account of the range, thickness, and fossils of the upper portion of the Rhætic formation—viz. the 'White Lias,' supposing that it really belongs to this, but to which it is now generally assigned, showing that it is very rarely seen in conjunction with the underlying shales, and that where they occur in one or two important sections the White Lias is absent. A list of the fossils is given, which are few and ill-preserved, *Ostrea intusstriata* and a species of *Avicula* (*Monotis*) being the most characteristic. A full account is given of the succeeding grey and black Rhætic shales with occasional intercalated shelly limestone and sandstone; and though, as a rule, good sections are rare, there were certain railway-cuttings which laid open several very interesting and instructive ones, and enabled the author to obtain a series of characteristic fossils, including the Radiata, by no means common and local, the *Ophiolepis Damesii*. It was stated that these occupied a considerable area in the southern division of the county, appearing again on the north-east, near Rugby, and as a rule succeeded by the basement beds (insect and saurian beds) of the Lower Lias, which were in places seen in conjunction with these shales. It was further observed that they probably underlie the Lias in its course through the county; and the author concluded by showing the general range of the Rhætics from the coast of Devon to the coast of Yorkshire; which, although not comparable either in thickness or abundance and variety of fossils with the rich, varied, and peculiar

Continental series, is still sufficiently marked and important in this county and elsewhere to make it a distinctive and independent formation.

VIII.—On the Silurian Rocks of North Wales. By Professor T. M'Kenny Hughes, M.A., F.G.S.

THE author begins by describing some sections in the Silurian rocks of North Wales. Some of them are in the lower part, some in higher beds. He gives lists of fossils from the various horizons in each. He then, by means of these and by what he calls syntelism, that is, the occurrence of similar sequences of beds of the same characters, lithological or other, points out the corresponding parts of the various sections described.

He then does the same for the Silurian of the eastern borders of the Lake district, and, having in this manner constructed a vertical section of each, compares the two districts and shows that there is an identical series in each, with all the important zones of one represented in the other, except that in the part of North Wales which he has worked out he has not yet detected beds as high as the newer part of the series in the Lake district.

IX.—Notes on some Sections in the Arenig Series of North Wales and the Lake District. By Professor T. M'Kenny Hughes, M.A., F.G.S.

IN this paper the author describes a number of sections which cross the Arenig series in different parts of England and Wales, and endeavours to explain some apparent discrepancies in what is generally a remarkably constant set of beds.

He starts with the Portmadoc section, where he considers that the chief differences of opinion have arisen from mistakes in the explanation of the geological structure of the district, especially from the wrong identification of some grit bands on opposite sides of important faults.

Following the series to the north he shows that, although they vary in thickness, the principal zones are still represented near Carnarvon; and, discussing the question of the unconformity of these beds on the Lower Cambrian, he points out that the Lower Cambrian rocks are seen to vary so much both in character and thickness within short distances in the neighbourhood of the existing outcrop of the Archæan that any argument founded upon their thinning-out or their different texture must be received with distrust in an area where they are known to have been deposited on the flanks of mountain ranges of pre-Cambrian age.

He then describes some localities in the Lake district where the occurrence of the same zones has been determined, and points out the difficulty of getting rid of such great thicknesses of deposits of fine mud as would be implied in the usual interpretation of those areas.

X.—On the Pleistocene Deposits of the Vale of Clwyd. By Professor T. M'Kenny Hughes, M.A., F.G.S.

THE author cautions observers against inferring too hastily the glacial origin of beds from their containing glaciated boulders.

He describes the drifts of the western part of North Wales, grouping them under two heads:—

1. The Older or Arenig Drift, or that in which boulders were transported from Arenig into the Vale of Clwyd; and

2. The Newer or Clwydian Drift, or that due to the destruction of the older glacial deposits by marine action, during which boulders were carried on floating ice from the north, and flints travelled in the shingle round the coast. All the shells found in it are of species still living on the adjoining coast: but some of the shells found in what he considers part of the same series of deposits in neighbouring districts are of a more arctic type, and may beleng to an earlier part of the same epoch.

He then gives an account of the principal caves explored about the Vale of Clwyd, and explains their relation in each case to the drifts of the district; inferring that, while some of them may be older than the marine Clwydian drift, and some may possibly be even preglacial, yet that none of the bone-deposits so far found in any of them can be referred to so early a date.

XI.—Supplementary Note on Two Deep Borings in Kent. By W. Whitaker, B.A., F.G.S., Assoc.Inst.C.E.

THE paper "On Deep Borings at Chatham," communicated in abstract to the last meeting of the Association, was afterwards read, with various additions, to the Geological Society. Since then, however, further information has been got, some of which is of importance, especially in view of the fact that the South Eastern Railway Company is about to make a deep trial-boring at Dover.

The boring at Chattenden Barracks, near Chatham, has been finished, being taken to a depth of over 1160 feet, the bottom of the Gault being reached at 1162 feet, where sand (Lower Greensand) was found and water got. In my account of the section it was left, in Gault, at 1103 feet, and I ventured to say that "some 60 feet more would reach the bottom of that formation"; this happened in 59 feet. I did not venture, however, to predict the finding of Lower Greensand, as, from the thinness of that series at Chatham, a little southward, it was quite possible that it might soon disappear northward.

The almost exact correspondence of the combined thickness of Chalk and Gault here, 872 feet, with the same total at Chatham (875 and 878 feet in two borings) is noteworthy. Of course there is no Upper Greensand, which formation is absent at the outcrop on the south.

The Dover boring has been carried a few feet deeper and abandoned. I have visited the site, and procured a good set of specimens of the bottom clays, of which we had but a few small pieces before.

These specimens have been carefully examined, and the result of this examination is, I think, worthy of notice. As regards fossils it is simply negative, my colleagues, Mr. G. Sharman and Mr. E. T. Newton, after washing and sifting pieces of many specimens, were unable to detect any organism, with a solitary exception, and *that* was a simple example of a species of *Rotalia*, which, struggling into existence in Silurian times, has managed to survive to the present day! I have some doubts, too, whether this one fossil may not have fallen

down the bore. Anyway it proves nothing. As regards the character of the beds, however, I think that a reasonable conclusion may be inferred from the specimens.

In my published account certain beds are referred, with some doubt, to the Lower Greensand. The reference is wrong and the doubt right, for the top five feet, of the 49 credited to Lower Greensand, really belong to the base of the Gault, and the bottom thirteen feet to the Wealden, as I believe. The Lower Greensand is left, therefore, with only 31 feet of clayey sand. It is curious that specimens from the bottom part (838 to 848 feet) are exactly like the corresponding specimens from the bottom part of the Lower Greensand in the Chatham boring (932 to 943 feet), the two sets having about the same vertical extent (10 or 11 feet).

These specimens remind one of the division known as the Sandgate Beds, and I am inclined to think that this division alone occurs at Dover, the Folkestone Beds above and the Hythe Beds below having thinned out, although both those divisions are thicker than the Sandgate Beds at the outcrop.

The clayey beds beneath have been proved to a thickness of some 80 feet, the boring ending at about 930 feet. In my paper I spoke of chalky matter occurring in them, but in this I was wrong. The white specks in the small specimens first seen certainly looked calcareous, but the examination of better specimens has shown that they are anything but that. Indeed, the prevailing character is the absence of any effervescence when the clays are treated with hydrochloric acid; in many cases peculiarly fine-grained whitish beds simply absorb the acid, without any effervescent action.

On comparing the specimens with other clays, they were found to be unlike any of the marine Cretaceous and Jurassic clays, and it seemed to me that their affinities lay rather with the Wealden series, and probably with the lower, or Hastings division, than with the Weald Clay.

I have only lately been able to test this by the help of a set of specimens that Mr. G. Maw has been kind enough to send me. On examining them I found that three specimens of Weald Clay, from Surrey, effervesced readily, which is perhaps not surprising as they came in two cases from close to Horsham stone, and in the other from near a Paludina-bed. Nine specimens from a more distant district, Dorsetshire, did not effervesce; but one can hardly give the exact position of these in the Wealden Series. Ten specimens from the Ashdown Series, the lowest division of the Hastings Beds, not only, in some cases, resembled Dover specimens in character (I speak from memory, not having had the two sets side by side), but in every case refused to notice the presence of hydrochloric acid.

Should this classification be right, it serves to strengthen very much the conclusion, in my paper, that Dover is on all grounds a good site for a deep trial-boring,[1] for it looks as if the bottom part of the great Wealden Series came there within 600 feet of the surface in the low ground, the boring being described on a site 280 feet above the sea.

[1] Quart. Journ. Geol. Soc. 1886, vol. xlii. p. 44.

REVIEWS.

I.—Department of the Interior. Report of the United States Geological Survey of the Territories. F. V. Hayden, United States Geologist-in-Charge. Volume III. The Vertebrata of the Tertiary Formations of the West. Book I. By Edward D. Cope, Member of the National Academy of Sciences. (Washington, Government Printing Office, 1883.)

(*Continued from p.* 477.)

THE rocks of Middle Tertiary Age, which are found in the far west of the United States, are calcareous clays and marls, alternating with light-coloured sandstone. In Oregon they are often old trachytic muds, three to four thousand feet thick, and about 2300 feet thick in Nevada. But on the White River in Nebraska the thickness of these rocks is reduced to 150 feet, and there the strata are divided by Hayden into eight zones. The Oregon beds are typically seen on the John Day River, so that the White River and the John Day beds are regarded as equivalent, and belong to the Miocene series. These rocks hitherto have yielded no Fishes or Amphibia, and no traces of Birds; so that the discussion of their fauna is limited to Reptiles and Mammals.

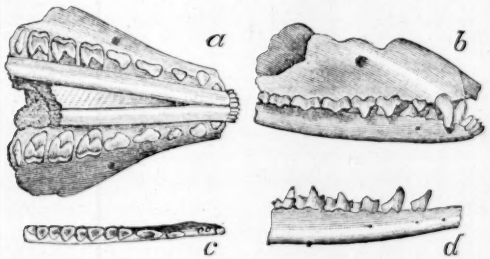
The striking feature of the reptilian life, as compared with that of the older Eocene series, is the absence of Crocodiles, the decrease in number of species of Tortoises, with an increase of Lizards and Serpents. But none of the Reptiles are remarkable for size, and are similar in proportions to those now living in the same region. The author commences with the genus *Testudo*, which is represented by five species in the White River beds of Colorado. They are distinguished by the form of marginal bones, the shape of gular scutes and other characters. *T. quadratus* is the largest, *T. laticuneus* the best preserved. Some of the species are only described from a few bones, because the difficulties of transport compelled the author to select such as were most characteristic, often leaving the bulk of the specimens behind. The only other Chelonian is Leidy's *Stylemys nebrascensis*.

The Lizards are for the most part founded upon fragmentary remains. *Peltosaurus*, however, is well preserved. In this genus the temporal fossa is not roofed over by bone, but is rather small; the orbits are large. Two median dermal scutes, which represent the interparietal and postinterparietal plates, have left impressions on the parietal bone. The genus is distinguished from *Gerrhonotus*, by having had the body covered with bony scutes, which were rectangular, and arranged in transverse bands, joined at the sides by minute sutures, and overlapping in an imbricated method. The hexagonal scutes on the skull are one of its most distinctive characters; one species is known. *Exostinus*, very imperfectly known, appears to be related to *Peltosaurus*, but that genus has the frontal region much wider, and wants the tubercles along the supra-orbital border. *Aciprion formosum* is a Lizard known from a dentary bone,

with closely-packed cylindrical pleurodont teeth, having compressed crowns with three cusps, the median one large and those at the sides small. *Diacium quinquipedale* is founded on a sacral vertebra which has no trace of a neural spine: and indicates an animal as large as any of the living Iguanidæ. The genus *Platyrhachis* is only known from vertebræ which have the centra much impressed, the neural spine reduced to a low keel, and the ridge connecting the zygapophyses deeply notched, a character which distinguishes these vertebræ from those of *Peltosaurus*: three species are known. *Cremastosaurus carinicollis* is a Lizard known from cervical vertebræ, somewhat like those of *Phrynosoma cornutum*, but with relatively small cup and ball articulations, and a strong rib-like hypapophysis.

There are four genera of Snakes founded on vertebræ, which are the only parts hitherto discovered. *Aphelophis* is very like the living genus *Charina*, though the zygosphene is wider. *Ogmophis*, known from two species, is an allied type, distinguished by the ridge which extends from the parapophysis, and the groove which lies between that ridge and the middle line of the centrum. *Calamagras* is a similar type, but intermediate between the two last named. *Neurodromicus* has vertebræ which resemble those of one of the Crotalidæ, but has no process below the prezygapophysis, and has the hypapophysis less robust.

The Mammalia of the White River period are not less numerous than those of the Bridger and Wasatch rocks, but a great change has come over the fauna. All the Amblypoda have disappeared, and there are no representatives of the Tæniodonta, Tillodonta, or of the Lophiodonts; while the Creodonta and Mesodonta are rare. No species of mammal found in these rocks is common to the underlying Eocene series. The Miocene species reach a larger average size, particularly among the Perissodactyla and Carnivora. Life would appear to have been abundant: for the author states that many of the species are represented by great droves, and their bones



Peratherium fugax.

form beds of considerable extent. The Marsupialia is represented by doubtful types, some of which have already been referred to the Creodonta, and are only placed with the Marsupials provisionally. *Peratherium*, though represented by six species, is only known from the cranium and mandibles. An excellent discussion is given of its dental characters, with the result that the teeth differ from those of

Didelphis in the elevation of the median cusps of the superior true molars into Vs, and in the tubercles of the external series becoming obsolete. All the species are founded on dental characters. *Mesodectes* and *Geolabis* are referred provisionally to the Creodonta. The former is intermediate between *Leptictis* and *Ictops*, the last premolar having a single sharp cusp as in the former genus, with an internal cusp or heel like that of the latter. The cranial characters are like those of *Leptictis*, and the molars and some other features recall the living genus *Solenodon*. The presternum has a prominent keel in front, like that of a bird. The cerebral hemispheres and cerebellum are a little wider than long, and together have a subquadrate outline. The only species known is about the size of the Hedgehog. *Geolabis* is only known from crania, from which the molar teeth are wanting, and the author is uncertain whether it may not be identical with *Domnina*. *Menotherium lemurinum*, though placed under the Insectivora, is regarded as the first indication of a Lemur in the Miocene of the United States, and indicates an animal as large as the domestic Cat. The genus *Domnina* is referred with some doubt to the Cheiroptera. It has the posterior external cusp of the true molar teeth in the form of a crescent, like the anterior cusp, only rather smaller; both internal cusps are at the summits of strong ridges: two species are described.

The order Rodentia is represented by no fewer than thirty-one species and eight genera, of which *Sciurus*, *Hesperomys* and *Lepus* are found living in the same region, and all the fossil species of Rodents belong to the three great divisions of the order which now inhabit North America. The author observes that the feet and teeth in this order present a succession of changes in structure with time. The earliest known forms, allies of the Squirrels, belong to the suborder Sciuromorpha. In them the trochlear structures of the humerus and tibia are but little developed, they are plantigrade, with five digits, and the fibula is not co-ossified with the tibia, while their teeth have nearly always long roots and short crowns, and are rarely prismatic. An advance on this generalized type is seen in the suborder Histricomorpha (which has a single representative in the Loup Fork beds), in many of its members having a reduced number of digits and prismatic dentition. In the third suborder, Myomorpha, the tibia is found co-ossified with the fibula; many genera have prismatic teeth, some a reduced number of digits, and a few, comprising the Jerboas, have the metatarsal bones blended together. Finally, the Rabbits add to these specialized characters a primitive character in the presence of four superior incisor teeth; and the author is disposed to believe that the Rodents are either direct descendants from the Marsupials, or that the Rabbits may represent the suborder Tillodonta of the Eocene. The differentiation of the Rodent suborders, however, must be anterior to the Miocene period, for the Squirrel tribe has already occurred in the Lower Eocene. The Myomorpha appear in the John Day beds, but without prismatic teeth, while the Lagomorpha are typically developed in the White River beds, and a true Porcupine represents the Hystrico-

morpha in the highest Miocene. There is, moreover, an interesting affinity between the extinct and living genera, in the circumstance that all the ancient genera differ from their modern representatives in the greater constriction of the skull behind the orbits, acccompanied by an absence of postorbital processes. The genus *Sciurus* is known from three species, two of which are about the size of the grey and red Squirrels of North America. *Gymnoptychus* appears to be a Squirrel nearly related to *Sciurus*, but differs in having the tubercles and crests of the molar teeth more complex than in any existing genus, except *Pteromys*. There are two species which differ in size and in proportions of the lower molar teeth.

Meniscomys is another type in which the dentition resembles that of *Pteromys*, but differs in the upper molars wanting the re-entering inflexion of the enamel. Four species are described, which differ in the length of the roots of the molars, in the character of the dental crests, and the plications of the inferior molar teeth.

It is observed that there is a suggestive resemblance between *Meniscomys hippodus* and *Haplodontia rufa*, now living in Oregon, which is indicative of a common origin. This ends the history of the true Squirrels.

Ischyromys is the type of a distinct family; for, though it resembles the Squirrels in dental characters, the infraorbital foramen occupies the position, at the origin of the zygomatic arch, seen in Porcupines and Cavies. The superciliary ridge and postorbital process, seen in most Squirrels, is lost; and there is a contraction between the orbits, which approximates towards the Beaver. Beavers are represented by two species of the genus *Castor*. *C. peninsulatus* is about the size of the large prairie Marmot, and is abundant in the Miocene rocks of Oregon. *C. gradatus* is somewhat smaller. *Heliscomys vetus* is the smallest Mammal of the White River beds, being about the size of *Mus musculus*. Its affinities are open to some doubt; the four inferior molars have crowns with four cusps in two transverse pairs and a broad ledge on the external side of the cusps.

The Myomorpha are represented by two families, Muridæ and Geomyidæ. *Eumys elegans*, of Leidy, is a Rat found in the White River rocks in Eastern Colorado, previously known from Dakota. The molar teeth are as large as those of the Norway Rat, but the muzzle only two-thirds as long, so that the animal was smaller and more robust. *Hesperomys nematodon* is a representative of an existing genus, and indicates a Rat as large as the red Squirrel. The genus *Paciculus*, which has three superior molars, differs from *Sigmodon* and *Neotoma*, in having three external inflexions of the enamel, instead of two, in the upper molars. *Entoptychus*, known from five species, is referred to the Geomyidæ. The molar teeth are four above and four below, rootless, with prismatic crowns, which differ from those of *Perognathus*, in having the enamel loop cut off and isolated. The skull wants the vacuities and large foramina seen in many Rodents. The bones of the skeleton in general resemble those of the genus *Thomomys*. The species are defined by the characters of the superciliary borders, the length of the skull, and width of the pre-

molars. The species are found in the John Day beds of Oregon. *Pleurolicus* is another member of the same family. It is represented by two species, and approximates to the existing genera *Heteromys* and *Perognathus*, from the latter of which the most distinctive difference is the grooving of the upper incisors.

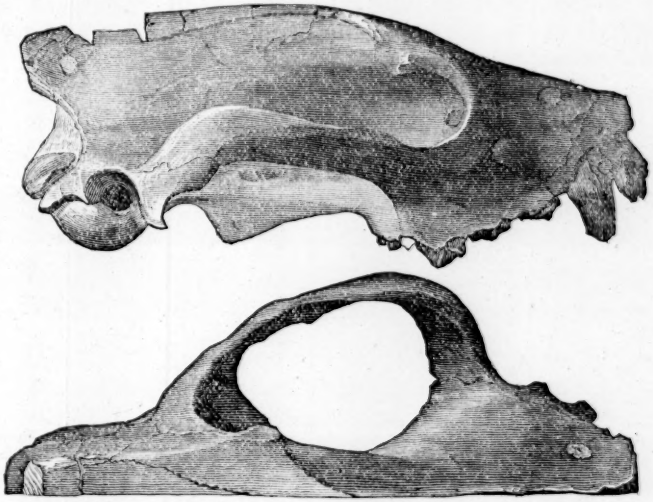
The Lagomorpha is represented by three genera. *Palæolagus* is a type which approximates towards *Lepus*, but it has no postfrontal process, and the first inferior molar consists of one column, more or less divided. A cast of the cerebral chamber shows that the olfactory lobes are large, expanding abruptly from the hemispheres, from which a constriction separates them. They are wider than long, and wider than the front of the cerebrum. The brain was smaller than in the Rabbit, and in the *Palæolagus haydeni* the cerebral hemispheres are smaller, and the olfactory lobes larger. The number of teeth is the same as in existing Rabbits, but with age many changes appear, which at first suggest the characters of different species.

P. haydeni was widely distributed in Dakota, Colorado, and Oregon. It is thought to have been the progenitor of *Lepus sylvaticus*, which now inhabits North America. *P. triplex* was rather larger than the prairie Marmot. *Lepus emisianus* is the only species of the genus found in the John Day River beds. It is distinguished by the free short postorbital processes, which are narrower than in *L. audubonii*, and behind these processes the cranium is narrower. The mandible has the form of *L. sylvaticus*, which the animal resembled in size. The remainder of the volume is devoted to the Carnivora.

From the views already developed by the author, it is interesting to find the Carnivora distinguished as clawed Mammalia with transverse glenoid cavity of the squamosal bone, confluent scaphoid and lunar bones of the carpus, and well-developed cerebral hemispheres. A good deal is made of the cerebral hemispheres, because some Insectivora possess a united scapholunar bone. Hence the crucial fissure of the hemispheres, which is present in all Carnivora, except one or two of the Melinæ, becomes as important a characteristic as the absence of the parieto-occipital, and calcarine fissures. The author makes two primary divisions of the order: first, Hypomycteri, in which the external nostril is occupied by the complex maxillo-turbinal bone, while the ethmo-turbinal bones are confined to the hinder part of the nasal fossa, and the inferior ethmo-turbinal is of small size; and, secondly, the Epimycteri, in which the external nostril is occupied by the inferior ethmo-turbinal and the reduced maxillo-turbinal. The Hypomycteri stand next to the Pinnipedia, since the maxillo-turbinal bone has the same anterior development in that group. The division of the groups into families depends upon the presence of sectorial teeth, which are defined as having at least two external tubercles, and by the flattening and emargination of their continuous edges, the sectorial blade is formed. Other characters are found in the number and form of the molars, the presence or absence of an alisphenoid canal, the character of the otic bulla and the number of toes.

The Canidæ were abundant in the Miocene of North America, but

in the lower and middle portions of the deposit the genera are allied to *Canis*, while in the Upper Miocene or Loup Fork beds the genus *Canis* prevails. Eight genera of Dogs are here represented by twenty-five species. *Amphicyon* of Lartet is known from three species. *A. cuspigerus* is not larger than the Kit Fox; *A. hartshornianus* is about the size of a Coyote, and *A. vetus* rather larger. *Temnocyon* has four species, and is distinguished from *Canis* by the presence of a cutting edge on the superior face of the heel of the inferior sectorial, in place of a double row of tubercles surrounding a basin. This keel is a repetition upon that tooth of the heel seen in the posterior premolar teeth of many Carnivora. The genus approaches most closely to the French form *Cynodictis crassirostris*. On *Temnocyon coryphæus* the author observes that the dimensions were about those of the *Canis latrans*, but the face was short. The brain-case is smaller than in the Coyote. The genus *Galecynus* of Owen is well represented by four species, which are characterized by the relatively small size of their sectorial teeth. The internal

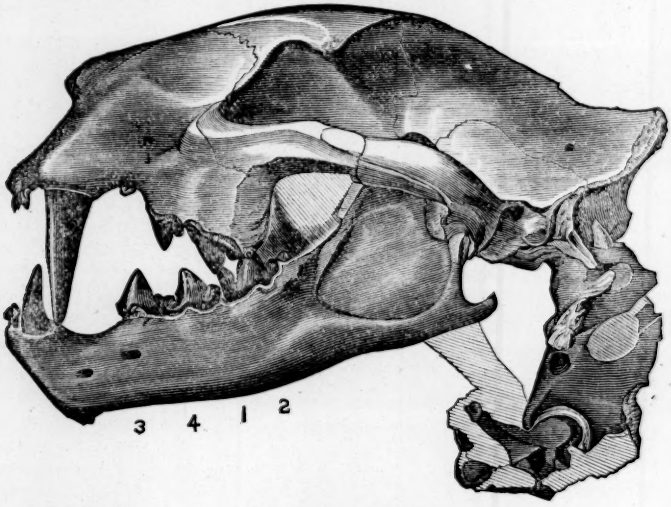


Enhydrocyon stenocephalus.

tubercle of the inferior sectorial is more largely developed than in the later species of Dogs, and thus approaches some of the Viverridæ. The genus is separated from *Canis* by the presence of the epitrochlear foramen of the humerus, a character shared with *Amphicyon* and *Temnocyon*. *G. gregarius* is only about half the size of the Red Fox. *G. geysmarianus* was about the size of *Mustela pennanti*: it stood lower on the legs than a Fox, had a body as slender as the most vermiform of Weasels, and a tail as long as in the Ichneumons. *G. lemur* is the smallest species yet discovered in the Miocene of Oregon. *Enhydrocyon* has the canine type of dentition, but in the form of skull resembles the Polecat and Otter: but one species is known, which was probably as large as the Coyote.

Oligobunis crassivultus differs from *Icticyon venaticus* of Brazil, in the greater development of the inner part of the upper tubercular molar, while the tubercular molar of the lower jaw is much less developed. *Hyænocyon* differs from *Oligobunis* in wanting the first premolar and the second molar teeth in both jaws. *Bunælurus* is allied to *Putorius* and perhaps to *Gulo*, but is distinguished by the form of its tubercular tooth, which is a cutting tooth without cusps or tubercles.

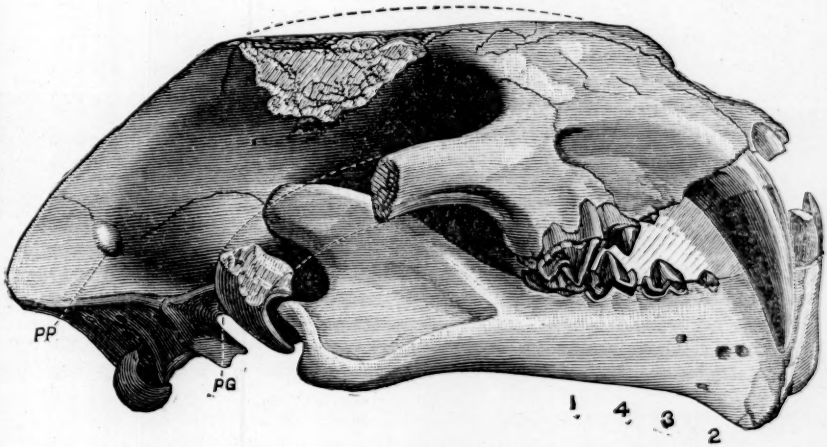
In the higher genera of the family Nimravidæ, the dental characters are like those of the Felidæ, but among the lower genera the number of molar teeth increases anteriorly in the upper jaw, and at both ends of the series in the lower jaw; though the number of true molars never exceeds one above and two below. Eight genera are at present grouped in this tribe; and they show modifications in the reduced number of molars, the enlarged size of the upper canines, smaller size of the lower canine, conical form of the crowns of the incisors, addition of a cutting lobe to the anterior base of the upper sectorial tooth, the obliteration of the inner tubercle of the lower sectorial in which the heel is lost, and in the development of cutting lobes on the hinder borders of the larger premolar teeth.



Nimravus gomphodus.

Some of these genera may belong to the Cryptoproctidæ; but until the number of digits is known in all the forms, this point cannot be determined. *Archælurus debilis* was an animal having much the aspect of existing Cats, but with more slender feet, narrower head, and greater convexity of the region between and behind the eyes. The prehensile organs of the feet, and teeth, were less robust. It was about the size of the American Panther. There is no cutting edge to the front of the canine tooth, and the posterior edge is not serrated. The sectorial teeth have a long narrow form, the superior

tooth has no anterior lobe, and the inferior tooth has no internal tubercle, but the heel is present. *Nimravus* is known from two species nearly allied to *Archælurus*, but distinguished by wanting the anterior premolars in both jaws, while the large canine in the upper jaw is denticulated. In dental formula and characters, it resembles *Hoplophoneus*, with the addition of a tubercular inferior molar tooth There is no evidence to show the length of the body. The canine teeth were probably exposed; and, as penetrating weapons, are unrivalled among carnivorous animals. Three species of *Dinictis* are described; it is a primitive sabre-tooth genus, closely connected with the false sabre-toothed group. The superior canine is long and compressed, and rests against an inferior marginal flange of the mandible, whose surface is divided from that of the symphysis by a strong angle. *Pogonodon* connects *Dinictis* with the higher sabre-toothed genera, but wants the tubercular lower molar of *Dinictis*, while it possesses the second inferior premolar which is wanting in *Hoplophoneus*. The species are the largest of the North American sabre-tooths.



Pogonodon platycopis.

P. platycopis is equal to the largest *Drepanodon*, and only inferior in size to *Smilodon*. The skull is equal in size to the largest Brazilian variety of the Jaguar. The molar teeth are rather small, the second sectorial is primitive, and peculiar in its robust heel. *Hoplophoneus* is a genus with the dental formula of *Drepanodon* and the true Cats, but which retains the primitive form of the sectorial teeth in the lower jaw. The type-species was as large as the Canadian Lynx, with long and slender upper canines. Three species are described. Here Book i. terminates, leaving the remainder of the John Day fauna, as well as that of the Pliocene period, for description in the second book of volume iii. The beautiful plates by which the text is illustrated reflect credit upon the artists, as well as upon the

Government Department which issues them, and will always make this work one of the standard landmarks in the history of Mammalian life.

As we close the book, it is with an earnest desire that the same devotion of the Department of the Interior to the interests of Science which has placed this magnificent contribution before the world, may at no distant date be able to secure the publication of the remainder of the author's contributions to a knowledge of the fossil Vertebrata of the United States Territories. It is, we believe, known that the materials for these histories have been in part gathered by many adventurous explorations, and not inconsiderable expenditure by the author; and that the United States Government has already spent large sums of money in preparing plates to accompany the text, which remains in their hands unused. We venture to believe that the gratitude which scientific men feel for the work already published, emphasizes the hope that it may be speedily completed; for it is one of the most valuable contributions to knowledge ever made by an individual, and its publication reflects honour on the nation.

When we survey the enormous range of Professor Cope's work, which has enriched every department of the Vertebrata with new materials, often interpreted with strikingly original conceptions, it is impossible not to bear witness to the magnitude of labours which derive their chief value from the genius which directs them. Shortcomings are easily detected, but when balanced against valuable achievements, may well be passed over. Most of the great writers on similar subjects in the Old World have secured honour by selecting for their labours, materials more or less perfect, which left no doubt on their interpretations. Obscure and difficult specimens have been laid on one side until later discoveries or maturer powers in the writer, removed the obscurities. Professor Cope, on the other hand, has never shrunk from any difficulties which his materials presented. A tooth, or a fragment of a mandible, or an ankle bone in his hands has revealed a new type of life. The discoveries which other men have waited for, for half a lifetime, he has utilized as the fossils successively came to hand, so that the nomenclature of his species has changed, and the interpretation of organic structures has gradually unfolded results of increasing value. There is hardly any writer whose work, looked back upon after a quarter of a century, does not show that, here and there, interpretations might be improved. Such improvements Prof. Cope has been able, in many cases, to make in a much shorter time by unceasing industry, and vigilance to seize new truths as they appeared. Work like this, upon fragmentary fossils, appeals with most powerful interest to those whose knowledge enables them to appreciate this daring faith in scientific methods, which is hedged round with reasons for the results proclaimed. And it is only when these earlier judgments are in so many cases sustained by later work on better specimens, that the discriminating insight manifested justifies such methods of work.

The results at which the author has arrived in this first book of

volume iii. are modestly stated by himself under fifteen heads, including such matters as the discovery of the Laramie genus *Champsosaurus* in Tertiary beds, the discovery of Tertiary allies of *Plagiaulax*, the discovery of five families and many genera of Creodonta, the discovery of the Periptychidæ, the Meniscotheriidæ, the Phenacodontidæ, the discovery of characters of the suborder Condylarthra, the characters of the Pantolambdidæ, of the suborder Taligrada, of the Anaptomorphidæ, the reconstruction of *Hyracotherium* and *Hyrachus*, the discovery of many Marsupials in the Lower Miocene, and of ancestors of the Cats and Dogs; to which may be added the description of three hundred and forty-nine species, all discovered by the author, except thirty-two. But although the present volume may not claim to have first set forth the greater results to which these are but some of the stepping-stones, we may point to the method of comparison of the fossil types with each other and with living genera as indications of the sources of knowledge by which the grouping of families and genera has been produced, which has given rise to new ordinal and sub-ordinal groups and improved classifications. The conception of the Bunotheria will always remain one of the most interesting of these results, because it is the first attempt to apply the principles of evolution to Mammalian classification in its larger grouping. The Amblypoda introduces a new hoofed type of life, which was already elaborated by the descriptions of Coryphodon, given in Lieutenant Wheeler's Survey in 1877. These and a multitude of minor innovations in classification are the fruits of new knowledge gathered partly from animals still living, partly from the wonderful organisms discovered in United States rocks. It is not too much to say that the light thus thrown upon the Mammalia as a whole, is more instructive as to the laws of life, and the conditions under which the component structures of animals have varied, and been evolved, than the insight gained during the same time by the study of Embryology. This harvest of fruit from the past may justify the confidence that in the history of fossil life, which has yet to be told by the palæontologist, the significance of the varied organization of existing animals will be demonstrated.

H. G. Seeley.

II.—M. L. Dollo on new Chelonians from the Eocene of Belgium.[1]

In these two memoirs the learned Assistant Naturalist to the Royal Belgian Museum of Natural History describes two new genera of Chelonians which are of very considerable interest, and also publishes a synopsis of the classification of the order, which is a modification of that proposed by Prof. E. D. Cope, of Philadelphia.

[1] "Les Chéloniens du Bruxellien (Eocène Moyen) de la Belgique," Bull. Mus. R. Hist. Nat. Belg. vol. iv. 75-86, pls. i. ii. (1884), "Les Chéloniens Landeniens (Eocène Inférieur) de la Belgique," *Ibid.* pp. 129-141, woodcuts.

The proposed classification is as follows:

Order Chelonia.
Suborder 1. Prochelonia.—Sect. Macelognatha.
2. Euchelonia.— „ 1. Athecæ.
„ 2. Thecophora.
Subsect. 1. Pleurodira.
2. Cryptodira. a. *Dactyloplastra.*
b. *Clidoplastra*
c. *Lysoplastra.*

The first suborder is a purely hypothetical one, and is formed for the ancestors of the known forms which are presumed to have been furnished with teeth. Apart from the general question whether it is advisable to overload scientific nomenclature with terms for hypothetical groups, it appears to us that in this instance the author would have exercised greater discretion if he had refrained from proposing this suborder, since, as Prof. A. Newton has recently shown in the case of the Birds, it does not necessarily follow that the possession of teeth by the more primitive forms of a group entails the separation of such forms from the more specialized groups which have lost these organs.

The Euchelonia comprehends all known members of the order; the section Athecæ being formed for *Sphargis* and its fossil allies; while the section Thecophora includes all other known forms. The first subsection (Pleurodira) of the latter embraces the existing family *Chelydidæ* and certain Mesozoic forms such as *Plesiochelys*. The existing members (*e.g. Chelys*, *Platemys*, and *Hydraspis*) of this subsection, which is characterized by certain features of the pelvis, and the presence of an intergular plate, are now entirely confined to the Southern Hemisphere; and it is interesting to note that while *Platemys* is represented in the Lower Eocene of England, a member (*H. Leithi*) of the South American genus *Hydraspis* has been described by Dr. Gray from the Eocene of Bombay. In the Cryptodira, which may be now regarded as the Chelonians of the Northern Hemisphere, are included all the remaining members of the order. In the first (Dactyloplastra) of the three groups into which this subsection is divided, M. Dollo recognizes four families,—the *Chelonidæ*, *Propleuridæ*, *Trionychidæ*, and *Chelydridæ*. The second group (Clidoplastra) is divided into the *Pleurosternidæ*, *Baënidæ*, *Adocidæ*, *Emydidæ*, *Cinosternidæ*, and *Testudinidæ*; while the third (Lysosterna) comprises only the *Cistudinidæ* (*e.g. Cistudo*, *Terrapene*, etc.).

We are by no means sure whether such a complicated division of the Cryptodira is advisable, especially as some English systematists (*e.g.* Dr. Sclater[1]) include the *Cistudinidæ*, *Cinosternidæ*, *Chelydridæ* (*e.g. Chelydra* and *Macrochelys* or *Macroclemmys*), and apparently the *Baënidæ* (*i.e.* if *Dermatemys* be classed in the latter) in the *Emydidæ*, and do not consider the characters on which M. Dollo relies as of more than generic value. This is, however, a matter on which every scientist who has studied the group is entitled to use his own opinion.

Turning now to the new forms described by M. Dollo, perhaps

[1] See "List of Animals in Gardens of Zool. Soc." 8th ed. pp. 561-571 (1883).

the most interesting is the one from the Bruxellien, to which he applies the name *Pseudotrionyx*, and classes in the *Chelydridæ*. This form is characterized by the absence of horny plates and the presence of a scute-sculpture, like *Trionyx*, but was apparently furnished with a complete series of marginal scutes, while the plastron, although only imperfectly united to the carapace, is much more complete than in the latter. This genus evidently forms a connecting link between the typical *Trionychidæ* and those Tortoises in which the shell is complete; M. Dollo attaches more weight to the apparent completeness of the marginal scutes than to the sculpture of the scutes and the absence of horny plates, and therefore separates the genus, together with *Anostira* and *Apholidemys* of Leidy from the *Trionychidæ*; but we cannot help thinking, from the variations in the former respect between *Trionyx* and *Emyda*, that the arguments are at least as strong in favour of the opposite view, and for taking the presence of horny plates as a characteristic of the *Emydidæ*, in the sense in which that term is used by Dr. Sclater.

The second genus, *Pachyrhynchus*, is from the Lower Eocene, and is referred to the *Chelonidæ*; it is represented not only by the typical Belgian *P. Gosseleti*, but probably also by the three forms from the London Clay described by Professor Sir R. Owen under the names of *Chelone longiceps*, *C. planimentum*, and *C. trigoniceps*. The genus is distinguished from *Chelone* by the great length of the mandibular symphysis; by the triangular form, thickness, and slight depression of the palate; the depth of the latero-temporal notches; the separation of the nasals; and by the posterior nares being separated from the anterior ones by long narrow channels, and by opening on the posterior third of the basal aspect of the cranium. These differences M. Dollo is inclined to regard as of rather more than generic value.

M. Dollo is to be congratulated on this paper, and especially on the careful diagnosis of characters distinguishing all his work.

R. L.

CORRESPONDENCE.

THE VOLCANIC ERUPTION OF NEW ZEALAND.

Sir,—Almost every geologist will have read the deeply interesting accounts and speculations by Mr. Archibald Geikie and Dr. Hector in "Nature," and of Mr. R. Etheridge, jun., in this Magazine. As the district affected is one likely to be subjected to a careful investigation, may I be permitted to draw attention to a few facts of important bearing on vulcanological science that should be cleared up. In my paper on the geology of Vesuvius and Monte Somma and in other communications, it was pointed out that after a long state of quiescence of a volcano, the subsequent eruption should be of the *explosive* or *plinian* type. That is to say, the stony products should consist essentially of pumice due to the length of time that

the magma had remained in contact with aquiferous strata, gradually absorbing water, and consequently the impossibility of the outflow of lava until all the water-saturated magma has been ejected. In relation with this the presence of the three divisions of the ejectamenta; the lowest or first being a very vitreous pumice, except for the presence of pre-eruptive minerals such as the felspars, amphibole, mica, and magnetite of first consolidation; the second or middle division being far more microlithic, with the presence of pyroxene or other eruptive or post-eruptive formed minerals; and the third or upper division consisting of ash due to the loss of cohesion within the magma in consequence of the advanced stage of conversion of the glassy part into "formed" or individualized matter.

In many tufas, and especially those formed from the third or upper division of the products of a *plinian* eruption, or of any pumiceous ash, there are an abundance of little pisolitic concretions of great perfection. Scrope has suggested drops of water falling in the dust as the cause of their production. To me they seem rather a segregation similar to what occurs in the felspathic and siliceous glazing cream in pottery manufacture; but there is still much doubt, and observation would be of much value if made on the new ash, as we do not know whether they are formed immediately, or after long exposure and soaking by moisture. One thing should be remembered, and that is, that a few small ones may be inclosed in a larger one, which is not compatible with Scrope's theory.

The next point is the vesicular structure in ashes, which often so well mimics that of lava, that in old decomposed rocks much doubt may exist as to whether a given mass may be a lava or a tuff. I think the drops of rain, suggested as an explanation of pisolites, is the real influence at work in producing these vesicular cavities.

Next, it would be interesting to know whether new cones (or more properly crater-rings) have been formed within the craters of explosion towards the end of the eruption.

Observations on the proportion of the *essential*, *accessory*, and *accidental* ejectamenta should be made in each of the subdivisions of the deposits, and at different distances from the centres of explosion.

Observations of the green and dry wood buried in the pumice would clear up the question as to whether the peculiar lignitization or carbonization to be seen at Pompei, not only in wood, but also in bread, fruit, cloth, grain, etc., is due to burning, baking, or subsequent decomposition. In Pompei neither glass nor lead was fused where buried by the falling pumice. This I have shown to be due to the low temperature of the pumice from the loss of heat in converting liquid or dissolved water into vapour on the relief of pressure during the eruption.

Lastly, search should be made for fulgurites, which have been met with at Pompei.

H. J. Johnston-Lavis.

THE PEA-GRIT OF LECKHAMPTON HILL.

Sir,—In the Quarterly Journal of the Geological Society just issued, there is a paper by my friend, Mr. Witchell, of Stroud, on "The Basement Beds of the Inferior Oolite of Gloucestershire."[1] The reasons for writing the paper are given under two heads, but I am only now concerned with the first. Mr. Witchell says:[2] 1. "That the beds called 'Pea-grit' in the Leckhampton section by Hugh Strickland, which name was adopted by Dr. Wright and the Geological Surveyors, included in that term—erroneously as I think—all the beds occurring between the Pea-grit proper, and the Cephalopoda bed of the sands, which beds are shown in some sections to be more than thirty feet in thickness."

Further on Mr. Witchell tells us that the "Pea-grit" and Basement Beds at Leckhampton Hill "are described as Pea-grit in the published works referring to them. Now, if Mr. Witchell will refer to the late Dr. Wright's paper,[3] "On the Palæontological and Stratigraphical Relations *of the so-called* Sands of the Inferior Oolite," he will find that in the section of Leckhampton Hill the lower beds of the Inferior Oolite are referred to as Pea-grit *and ferruginous oolite*." That Dr. Wright was fully aware of beds of oolitic structure beneath the "Pea-grit," and which he recognized as distinct from the particular bed bearing that name, is shown by his section of Cleeve Hill,[4] in which he gives the following:—

	ft.	in.
Pea-grit	21	30
Coarse ferruginous oolite	22	5

Edward Wethered.

NOTIDANUS AMALTHEI, OPPEL.

Sir,—During a recent examination of the fossil Vertebrates in the Whitby Museum, which I have been enabled to make through the kindness of Mr. Martin Simpson, I have been fortunate enough to meet with the Liassic tooth mentioned by Tate and Blake as referable to *Notidanus Amalthei*. This specimen, it will be remembered, was not forthcoming at the time of publication of my contribution to the Palæontology of the Notidanidæ (*antea*, p. 208), and it may therefore be interesting to add a brief note upon the features it presents.

The fossil consists merely of a single laterally-compressed cone, scarcely two millimetres in height, with a very minute denticulation at the base of one edge, and fixed upon a fragment of a root. The cone has an enamelled surface, and the one side is almost plane, while the other is strongly convex; and the appearance of the tooth is certainly suggestive of other cones having been broken away from the one that remains. There can be scarcely any doubt, indeed, that the specimen belongs to a Selachian genus, and it bears much

[1] Q.J.G.S. vol. xlii. part 3, No. 167, pp. 264—270. [2] *Ibid.* p. 264.
[3] *Ibid.* vol. xii. p. 295, 1856.
[4] Proc. Cotteswold Club, 1869, "Correlation of the Jurassic Rocks of the Côte d'Or and the Cotteswold Hills."

more resemblance to a dental fragment of *Notidanus* than the Swabian fossil described by Oppel, as far as the latter's figure will enable one to judge. It does not agree with the teeth of *Palæospinax* or any other Liassic Shark I have had the opportunity of studying, and Tate and Blake's determination is very possibly correct; but more satisfactory evidence must still be awaited before there is absolute certainty of the presence of *Notidanus* among the early Jurassic fauna.

A. Smith Woodward.

ENTOMOSTRACA IN THE RHÆTICS.

Sir,—In the Geological Magazine, May, 1886, p. 203, a slight error occurs in Mr. J. S. Gardner's interesting paper, in stating that "the valves of a species of *Cyclas* abound in the Rhætics." This should have been either *Candona* or possibly *Cypris*; the latter may be after all correct, as it is associated with the freshwater aquatic Moss, *Naiadites*. The supposed *Cyclas* has been determined to be *Estheria*, a brackish-water Crustacean, though Sowerby stated it to be *Cyclas*, when my work on Fossil Insects was published. In the Note (2) at the bottom the reference should have been not to the *Estheria* bed in particular, but to the Rhætics in general (in which the former is included), which may be considered to be junction or passage beds between the Trias and the Lias.

P. B. Brodie.

OBITUARY.

HARVEY BUCHANAN HOLL, M.D., F.G.S.

Born 28th September, 1820; Died 11th September, 1886.

This able geologist and palæontologist was son of the late William Holl, Esq., formerly of Worcester. After passing through Dr. Walter's School at Worcester, he entered the Medical College in Birmingham.

During this period of Harvey Holl's career, when he was only about 17 years of age, he became acquainted with Sir Henry de la Beche, and was invited by that distinguished geologist to accompany him in a geological reconnaissance through Devon and Cornwall. It was probably owing to this expedition (which extended over some six months) that young Holl became confirmed in his geological tastes, and for a time was led entirely to abandon his medical studies.

From the good opinion which Sir Henry de la Beche formed of Holl's work in the field, he recommended the youthful geologist to his friend Professor Rogers, of Philadelphia (who was seeking an assistant), and Harvey Holl started off to join his new chief and take a part in the Geological Survey of Pennsylvania. In this interesting region, Holl remained for about three years, and spent a year longer in the United States geologising on his own resources.

Upon his return to England, Holl entered as a student at St. George's Hospital, and successfully passed the Royal College of Surgeons in London. In 1859 he graduated as M.D. at King's College, Aberdeen.

On the breaking out of the Crimean War, Dr. Holl was appointed one of the Senior Civil Surgeons to aid the military staff, which was totally inadequate to the heavy strain laid upon it by the first year's severe trials and sufferings. He remained abroad until the end of the campaign, serving partly in the Crimea, but most of the time in the hospital at Scutari. On his return after the conclusion of peace with Russia, he settled for some years as a medical practitioner in St. George's Square, Pimlico.

Dr. Holl was remarkable for his extremely reserved and retiring habits and formed consequently but few friendships. Yet he was by no means a man of small ability. As a medical practitioner he might have attained great eminence, but he never was ambitious of fame.

An earnest student of Cryptogamic Botany, he has left some forty-seven volumes of carefully collected British Lichens, all arranged and named by himself. He was also a liberal donor to the Botanical Department of the British Museum.

As a geologist and palæontologist, he displayed great power, and his papers always met with high appreciation in the Geological Society. During his field-excursions he had formed a considerable collection of British fossils, among which were numerous species and varieties of the Silurian genera *Beyrichia*, *Primitia*, and their allies, in very perfect preservation. As a good microscopist, clever draughtsman, and careful observer, he willingly and ably co-operated with Professor Rupert Jones in the study and description of the older Ostracoda. Within this year even he warmly assisted in the work, and notwithstanding his declining health, he supplied new sketches and notes of his favourite little fossils.

Dr. Holl was well known among the leading members of the Hereford, Woolhope, Malvern, and Cotteswold Natural History Field Clubs, and was himself frequently present at their meetings and excursions.

Although an excellent palæontologist, he will probably be most widely known and remembered as an able and experienced geologist, and the papers which will best be recollected are those on the Geological Structure of the Malvern Hills, in which area he made great advances on the work of Prof. Phillips; and his memoir "On the Older Rocks of South Devon and East Cornwall," in which he exemplified the excellence in method of his early teacher in Devonian geology, Sir Henry de la Beche.

To those who had the pleasure to know him, and were able to penetrate beneath his ordinary reserve, he will be remembered as a genial and pleasant comrade, full of scientific information, and lasting in his attachment to his friends.

Dr. Holl was elected a Fellow of the Geological Society in 1862, and having about this time relinquished his practice, he removed to Tower Lodge, The Link, Malvern, where he again took up his favourite geological studies, and in 1863 communicated a paper to the British Association "On the Metamorphic Rocks of the Malvern Hills." [1]

[1] Brit. Assoc. Report, 1863 (part 2), pp. 70—73.

In the same year he also read a paper before the Geological Society of London, "On the Correlation of the several Subdivisions of the Inferior Oolite in the Middle and South of England."[1]

From Malvern Dr. Holl removed to Elderslie House, London Road, Worcester, and thence to Little Perdiswell, Worcester, where he resided until about the end of 1884, when, for the sake of his health, he removed to Cheltenham, living first at 3, Oriel Villas, and lastly at 1, Derby Villas where he died after three weeks' illness, resulting from heart disease.

Besides those already named, the following additional papers are credited to Dr. Holl, namely:—

3. On the Geological Structure of the Malvern Hills and adjacent District. Quart. Journ. Geol. Soc. 1864, vol. xx. p. 413, and vol. xxi. 1865, pp. 72-102. Phil. Mag. 1864, vol. xxviii. p. 243.
4. On the Pre-Cambrian Rocks of Central England. Brit. Assoc. Rep. 1865, vol. xxxv. (Sect.), pp. 59-62; Geol. Mag. 1865. Vol. II. pp. 563-565.
5. *Goniophyllum pyramidale*, Hisinger. Geol. Mag. 1866, Vol. III. pp. 430-431.
6. On the Geological Position of the Crystalline Rocks of the Malvern Hills. Woolhope Field Club Trans. 1866, pp. 273-274.
7. On the Older Rocks of South Devon and East Cornwall. Quart. Journ. Geol. Soc. 1868, vol. xxiv. pp. 400-454; Phil. Mag. 1868, vol. xxxvi. p. 158.
8. Notes on Fossil Sponges. Geol. Mag. 1872, Vol. IX. pp. 309-315, and 343-352.
9. The Epitheca in Fossil Sponges. Monthly Microsc. Journ. 1872, vol. viii. pp. 141-142.

He was also joint-author with Prof. T. Rupert Jones, F.R.S., of the following papers, viz.:—

1. Notes on the Palæozoic Bivalved Entomostraca. No. VI. Some Silurian Species (*Primitia*). Ann. and Mag. Nat. Hist. 1865, vol. xvi. pp. 414-425.
2. Notes on the Palæozoic Bivalved Entomostraca. No. VIII. Some Lower Silurian Species from the Chair of Kildare. *Op. cit.* 1868, pp. 54-62.
3. Notes on the Palæozoic Bivalved Entomostraca. No. IX. Some Silurian Species. *Op. cit.* 1869, pp. 211-229.
4. Notes on the Palæozoic Bivalved Entomostraca. No. XX. On the Genus *Beyrichia* and some New Species. *Op. cit.* 1886, pp. 337-363.
5. Notes on the Palæozoic Bivalved Entomostraca. No. XXI. On some Silurian Genera and Species. *Op. cit.* pp. 403-414.

MISCELLANEOUS.

Memorial to Dr. Thomas Davidson, LL.D., F.R.S.—Thursday was the first anniversary of the death of Dr. Thomas Davidson. The proposed memorial to his memory in the Brighton Museum will take the form of a life-sized medallion in marble, framed in alabaster. The work has been undertaken by Mr. T. Brock, A.R.A., through the kind offices of Mr. Edward Armitage, R.A., an old friend and former fellow Art student of Dr. Davidson's in the ateliers of Paul de la Roche. Mr. Armitage has contributed £20 to the "Davidson Memorial Fund," and his advice and assistance have been of great service to the Committee and Hon. Secretaries.—*Brighton Herald*, Oct. 16, 1886.

[1] Quart. Journ. Geol. Soc. vol. xix. (1863), pp. 70—73.

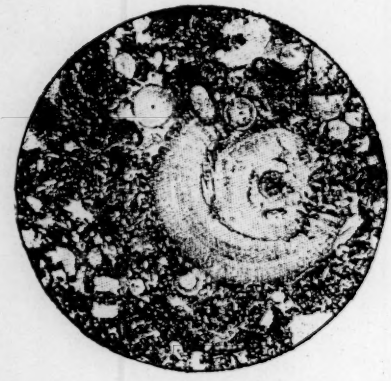


Fig 1. × 12 Diam.

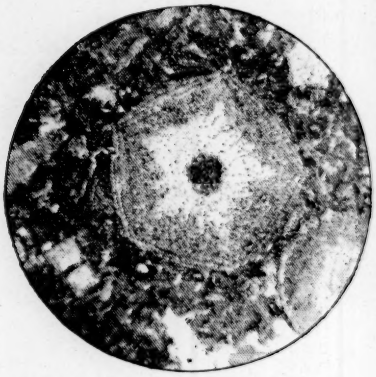


Fig. 2. × 22 Diam.

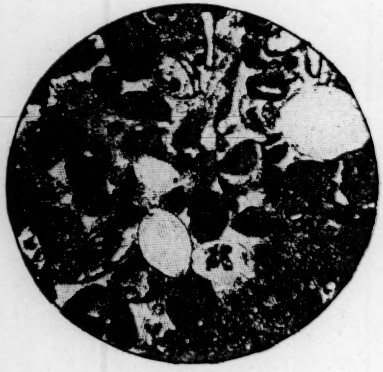


Fig. 3. × 22 Diam.

Fig. 4. × 22 Diam.

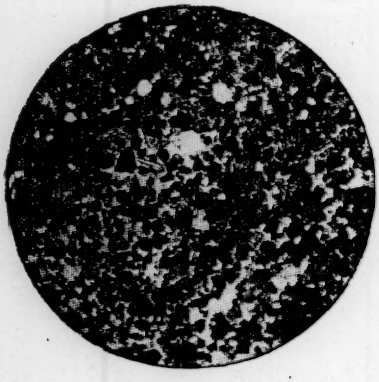


Fig. 5. × 22 Diam.

Fig. 6. × 12 Diam.

STRUCTURE AND ORGANISMS IN CARBONIFEROUS SHALES AND LIMESTONES.